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NUCLEAR SCIENCE, AN INTRODUCTORY COURSE.

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WILKES-BARRE CITY SCHOOLS, PA.

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THIS CURRICULUM GUIDE DESCRIBES A TWELFTH-GRADE INTERDISCIPLINARY, INTRODUCTORY NUCLEAR SCIENCE COURSE. IT IS BELIEVED TO FILL THE NEED FOR AN ADVANCED COURSE THAT IS TIMELY, CHALLENGING, AND APPROPRIATE AS A SEQUENTIAL ADDITION TO THE BIOLOGY-CHEMISTRY-PHYSICS SEQUENCE. PRELIMINARY INFORMATION COVERS SUCH MATTERS AS (1) RADIOISOTOPE WORK AREAS, (2) NUCLEAR SCIENCE LABORATORY, (3) PURCHASING EQUIPMENT, (4) CONSTRUCTION AND MODIFICATION OF EQUIPMENT, (5) LICENSING AND LEGAL REQUIREMENTS, (6) STANDARDS FOR PROTECTION AGAINST RADIATION, AND (7) THE SAFE USE OF RADIOISOTOPES. THE SECOND PART OF THE DOCUMENT PRESENTS A SUGGESTED SYLLABUS FOR A ONE-SEMESTER COURSE IN NUCLEAR SCIENCE, AND INCLUDES (1) CONTENT OUTLINE, (2) LEARNING EXPERIENCES AND LABORATORY EXPERIMENTS, (3) TEXT REFERENCES, AND (4) AUDIOVISUAL AIDS (ANNOTATED FILM LISTS). SUPPLEMENTARY SECTIONS INCLUDE (1) NUCLEAR SCIENCE REFERENCE MATERIALS, (2) ATOMIC ENERGY COMMISSION (AEC) PUBLICATIONS, (3) FILMSTRIPS PREPARED BY THE RADIATION SCIENCE SEMINAR STAFF, (4) AEC FILM SERIES, (5) SIMPLE EXPERIMENTS FOR HIGH SCHOOL STUDENTS USING THE CIVIL DEFENSE V-700 GEIGER COUNTER, (6) AUTORADIOGRAPHY PROCESSING FORMULAS, (7) NUCLEAR EDUCATION EQUIPMENT, AND (8) NUCLEAR EQUIPMENT SUPPLIES. (DH)

NUCLEAR SCIENCE

an introductory course

PREPARED BY THE STAFF

Radiation Science Seminar

Title III ESEA Project

Wilkes-Barre City Schools, Grantee

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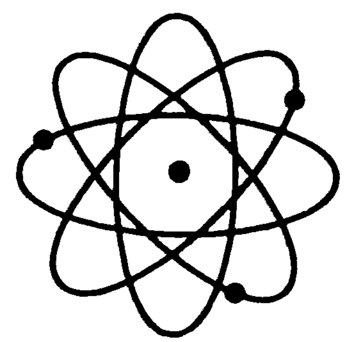
JOHN W. SULCOSKI, Director



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PREFACE

Since the first atomic explosion shattered the stillness over the New Mexico desert in 1945, the atom has never been more in the public eye. Since then, the radioisotope has saved more lives and made life easier for the world populace through its peaceful applications than the unfortunates who lost their lives in its military applications.

In those twenty years, the applications of radioactivity now touch our daily lives in an unheralded yet massive manner. From the electrical power to the radiation-gauged newsprint to the thyroid tests, few phenomena have yielded man so much. Yet the term "radioactive" still strikes terror in the minds of men as probably no other term. The misinformed and uninformed almost quake at the sound of the word. The most appalling and disappointing fact of all is that the majority of science teachers fall into this category. During the instructional phase of the "Radiation Science Seminar" program, the temerity in handling radioactive materials was far greater among the teachers than the student participants.

The staff of "Radiation Science Seminar" hopes that this curriculum guide will help erase this fearful attitude and promote the educational use of radioisotopes in our schools.

Nuclear Science and the Curriculum

Within the past decade, a noticeable trend in the nations' schools is that of moving the usual course sequence down one grade, so that in some schools biology is taught at the 9th grade level, chemistry at the 10th, and physics at the 11th. This sequence leaves a science elective open in the 12th grade for the science-prone student. This gap has been filled with an assortment of courses, such as Biology II, Chemistry II, Physics II, Organic Chemistry, Advanced Chemistry, Science Seminar, Great Ideas in Science, Astronomy, Physiology, and others dependent solely on teacher interest and the amenability of the local administration.

A closer look at the typical science track for the college-preparatory student shows this sequence:

7th grade - Introduction to Science (General Science)

8th grade - Earth Science

9th grade - Biology

10th grade - Chemistry

11th grade - Physics

12th grade - Elective (Biology II, Chemistry II, Physics II)

Note that of the six steps in the sequence, four courses are survey courses, while the first is an inter-disciplinary survey course and the last is a specialized offering. The course sequence is somewhat based upon order of importance and level of difficulty -- one builds upon the other. We hold that the needs of the student will be far greater met when he is exposed to a wide variety of survey courses rather than a specialized track, especially so early in his educational career. The colleges have pursued this policy successfully since their inception.

Science courses on the high school level apparently do three basic tasks:

(a) Teach basic concepts

(b) Teach basic skills

(c) Motivate

Educational psychology studies quoted in almost every text in introductory education and other studies show that the first two factors are in reality far less successful than the third factor. A recent study quoted in the "Journal of Chemical Education" showed that success in high school chemistry had little bearing on success in college chemistry; student fared about equally in college chemistry with or without a high-school preparation. The approach of the national alphabet programs also serves to point up the extreme importance of the motivation factor in high school science courses.

If a course in nuclear science were offered in the 12th grade as an elective, it would fulfill all three factors without repeating any parts of the sequence. The nuclear science course would be survey and inter-disciplinary. There is no more study fundamental than the study of the nucleus.

RADIOISOTOPE WORK AREAS

Adapting Existing Laboratories

The work areas in which radioisotopes will be used sometimes are of extreme concern to fledgling workers in this field. This extreme concern probably has its basis in the back-of-the mind fear of the radioisotope by workers just entering the portals of nuclear experiments.

If short half-life radioactive materials (such as I^{131}, Ga^{68}, P^{32}) are used intermittently throughout the school year and in tracer quantities, then the precautions given to common-place chemicals (such as H_2SO_4, KNO_3, etc.) will be sufficient. No special work area or caution signs will be necessary with microcurie quantities of the above radioisotopes.

When short half-life and long half-life radioisotopes are used constantly over the school year, more thought should be given to the choice of the work area. This extra thought is solely because of possible contamination affecting the background count of the instrumentation rather than any radiation hazard. Just as an ordinary chemist does not indiscriminately leave mercury spilled all over the lab, so a radioisotope worker should localize and minimize contamination. If the count rate in an experiment is only 300 cpm and the background count is 200 cpm, good data should not be expected.

Ideally, the counting area and sample preparation area should be in two different rooms to minimize possible contamination. In the situation where only a few instruments are available and not used constantly, such an ideal solution is economically impractical. However, it is usually no problem to place the sample preparation area on an opposite side of the room from the counting area

When space is so scarce that this divorcement is not possible, the same lab table can be used if the two areas are delineated by some type of divider. A wooden booth-type partition with ordinary house bricks to suppress background will effect a good separation of the two areas.

This student is preparing a sample with uranyl nitrate.

THE IDEAL NUCLEAR SCIENCE LABORATORY

The ideal nuclear science laboratory suite should consist of two rooms: the sample preparation room and the counting room.

The sample preparation room may consist of ordinary lab tables, covered with absorbent paper, and containing the usual utilities such as gas, water, and electricity. Both rooms should have a large amount of 110-V AC receptacles for the large number of electrical appliances which will be used. As in all laboratories, there should be a minimum of six feet and more ideally, eight feet between lab tables, and five to six lineal feet of work space for each worker or group of two workers.

A multi-drawer cabinet is needed for storage of the extremely small miscellaneous items, and also for micro pipettes, pipette controls, syringes, etc.

A large hood for work with radioactive gases is a necessity. This hood should be fully equipped. A small glove box is also a useful item. Many laboratories employ hoods for radioisotope storage by lining the three sides with lead bricks, but an ordinary side table will do for this purpose. A few layers of ordinary house bricks will cut down radiation emanating from the storage area; these bricks will also cut costs, as masonry bricks are about 20¢ apiece compared to the $8.00 for each lead brick.

For maximum decontamination ease in the event of spills on the floor, seamless floor covering complete with upsweep cove molding should be utilized. If ordinary vinyl or asphalt tile is used for the floor covering, spilled radioactive material may be retained in the cracks or seams.

Resourceful teachers have converted corners of supply rooms into counting areas; others have placed scalers in balance rooms; others have appropriated janitors' closets and converted them into perfectly acceptable counting areas. If license-exempt quantities of radioactive materials are the only type used, the ordinary general chemistry laboratory may be used for sample preparation with little if any conversion.

In the cases above, small quantities of radioactive waste may be kept in old, clean large-mouth 5-lb. chemical bottles. When the bottles are filled, they may be wrapped in a plastic bag and discarded with ordinary lab refuse. The refuse collection or janitorial staff should be informed that no danger exists in handling this waste. Surprising them with a large bottle with an eye-catching caution label affixed will most likely result in some uneasiness on their part.

Because of any possible misunderstanding by the public or the school administration if radioisotopes are appropriated by the curious or unstable student, it is good practice to keep the radioactive materials under lock and key. This practice is not unusual, as many schools keep chemicals like expensive silver nitrate, potentially-dangerous potassium cyanide and arsenic trioxide, and similar compounds under lock and key to prevent acquisition by unauthorized personnel. Even the simplest type of lock is a great deterrent to the curious.

A typical nuclear science counting room.

Purchasing Equipment

The appearance of the transistor has affected the design of nuclear science equipment with probably as much impact as the appearance of the Geiger tube. Transistorized, quality nuclear science instrumentation is now in range of almost every high school budget. A high school that can afford a two-pan analytical balance can afford a scaler; a high school that can afford a Mettler balance can afford two scalers. With NDEA funds, even modest budgets can be greatly extended. Schools with shop facilities can realize tremendous savings in nuclear accessories.

In a later section a suggested list of equipment for the nuclear science course will be found. The list has been chosen for maximum utilization at lowest cost.

In purchasing nuclear equipment, the following thoughts should be kept in mind:

1. Is the supplier reliable?
   Some suppliers of equipment offer materials at attractive prices, but of poorer quality. Service may also be poor. Worse yet, many companies exist only a year or two before bankruptcy.

2. Is the equipment versatile?
   Can the scaler of maker A be used with the G-M tube of maker B? Such interchangeability is highly desirable.

3. Is the equipment design suitable for high school students?
   A five-decade scaler with 7 u sec resolving time, preset count, and other features will not count license-free quantities of radioactive material any better than a two-decade-mechanical register scaler with 200 usec resolving time and ½" G-M tube. The latter will suffice at ½ to 1/3 the cost of the former and yield satisfactory results for educational purposes.

For those schools with modest budgets or with indefinite plans, one or two low-cost educational scaler systems may be adequately augmented with Civil Defense V-700 ratemeters borrowed from the local county Civil Defense organization. Civil Defense organizations are quite happy to lend V-700 units to qualified teachers who will put them to use. The CD V-700 unit may be adapted for educational purposes by simply constructing a tube stand for improved geometry.

CONSTRUCTION AND MODIFICATION OF EQUIPMENT

The teacher interested in utilizing nuclear experiments is set back at first glance by the seemingly high cost of the equipment needed for such work. Actually, a school which can afford an analytical balance can afford a G-M counting system. A school which can afford a Mettler-type balance can afford two or three G-M counting systems. A scaler and its associated accessories are capital items which have a long expected use life. NDEA funds can also be used for the purchase of nuclear science equipment.

Nevertheless, the resourceful instructor may greatly extend modest budgets by constructing many of the accessory items in the school shops. Larger schools now have shop facilities for construction

of devices from plastic, and with these facilities accessories may be constructed which will rival the commercial product in appearance, durability, and ease of usage.

Accessory items easily duplicated may include the following:

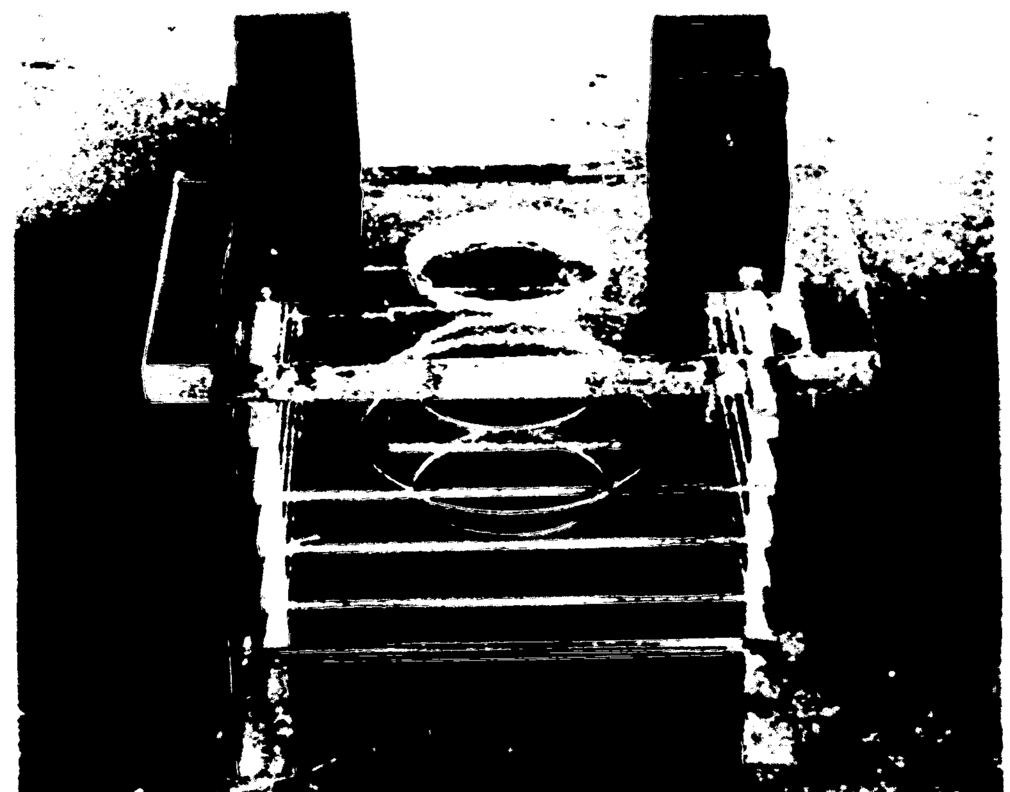
1. End-window G-M tube stands
2. Side-window G-M tube stands
3. Resolving time sources
4. Calibrated absorber sets
5. Calibrated experiment boards
6. Collimated sources
7. Storage cabinets
8. Sample trays
9. Card mounts
10. Backscatter kits
11. Electrophoresis apparatus
12. Chromatography apparatus

Shop teachers and talented students can construct these items quite easily if they are supplied with a sample from which to work. Lucite and Plexiglass plastic in ½", ¼", 1/16" sheet and 1¼" rods are necessary to make the items mentioned above. More detailed information may be secured from the RSS filmstrip,"Securing Inexpensive Nuclear Accessories."

In some cases, enough money saved by home-construction of the most expensive items, such as tube stands and calibrated absorber sets, may enable the instructor to purchase another scaler. Items like timers may actually be deleted from requisitions, since most students have watches with sweep-second hands.

Around 1958, every public school in the country was given a set of radiological monitoring instruments by the Office of Civil Defense Mobilization, including dosimeters, chargers, G-M counters, and gamma-survey meters. The most useful items are the two CD V-700 Geiger counters. In most schools in the U.S. these yellow boxes languish in corners and closets, in many cases their presence unknown to instructors who have entered science teaching after 1958.

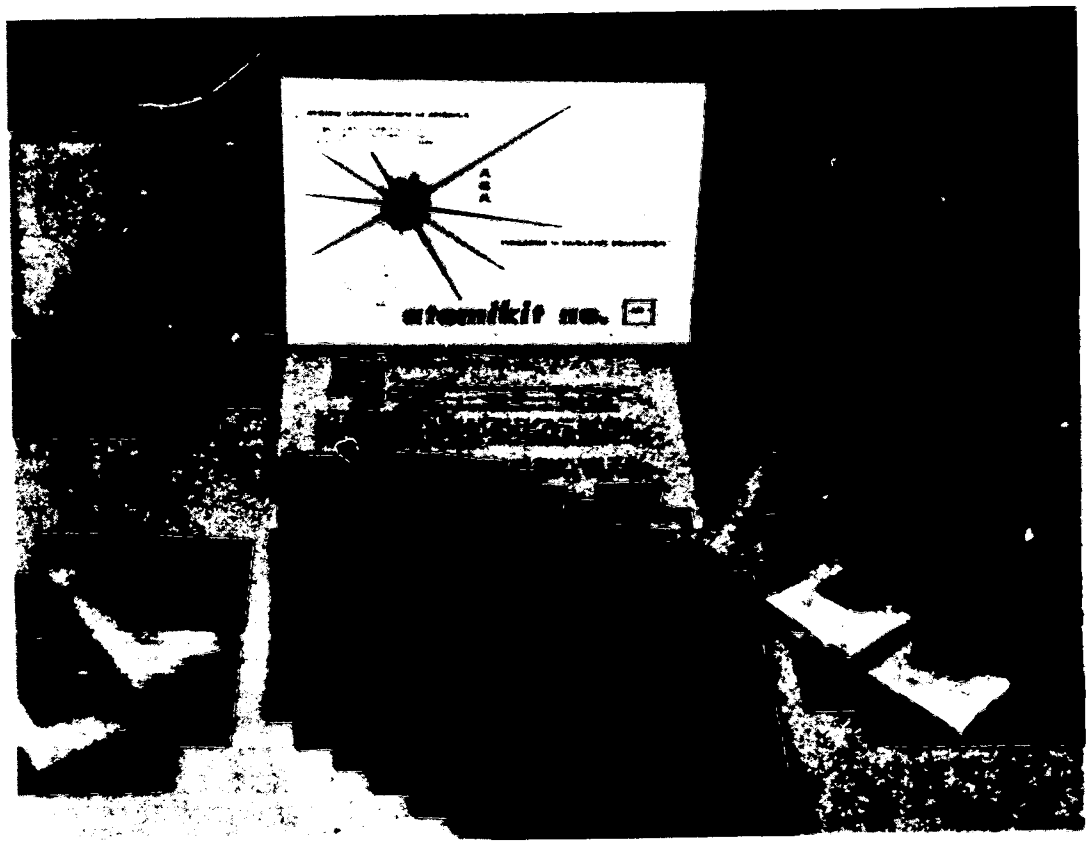
By merely adding two inexpensive broom clamps to a tube stand originally designed for end-window Geiger Tubes, it will effectively convert the CD V-700 G-M counter into an instrument capable of many exciting experiments. The constant geometry resulting from this adaptation enables experiments to be performed such as: half-life determination, backscattering, resolving time, absorption of radiation by sample, side-scattering, and many more normally performed only with scalers.



Simple tube stand for side-window tubes made from ¼" plastic and broom clamps.

Autoradiography, probably the most useful nuclear experimental procedure in biology, may be performed with optical sheet films available at most camera shops and processing solutions mixed from chemicals found in the ordinary chem lab. One company (Atomic Corporation of America) has developed an inexpensive autoradiography kit which needs no dark room for processing of the films. This process is also treated in an RSS filmstrip, "Autoradiography."

Autoradiogram of tomato plant showing distribution of P-32.



Shown above is the inexpensive autoradiography kit marketed by Atomic Corporation of America. With this kit, no darkroom is needed for autoradiography experiments.

LICENSING AND LEGAL REQUIREMENTS

Contrary to much popular belief among lay people and teachers, it is not necessary to possess any special license or to take any qualifying test in order to handle certain classes of radioactive materials. Radioactive byproduct materials fall into two broad licensing categories: specific license materials and general license materials.

Radioactive materials in quantities greater than those listed cannot be handled unless the person or organization possesses a specific license for that radioisotope. For example, if a school wishes to possess 5 millicuries (5mc) of P-32 it will need a specific license to do so. Applications to the AEC (or to the half-dozen or so states which have assumed control under agreement with the AEC) for a specific license will be based upon many factors including the training of the applicant.

However, 99% of all educational nuclear science experiments may be performed satisfactorily with generally-licensed quantities of radioactive materials (commonly called license-free or license-exempt in the trade). Every person in the U.S. is generally-licensed, and may possess up to 10 of the scheduled quantities as shown in the table. For example, a school may have in its possession at one time 10 bottles of 10 uc P-32, or 5 bottles of 10 uc P-32 and 5 bottles of 10 uc I-131, or 1 bottle of 50 uc C-14, 1 bottle of 50 uc Tl-204, 2 bottles of 50 uc Cr-51, and 6 bottles of 10 uc P-32, as each of the combinations equals the 10 scheduled quantities for liquid radioisotopes. (They may not be mixed together to achieve a great activity.) Note that this is a possession limit. The AEC recommends supervision of radioactive materials by experienced personnel. A year's work with P-32 or I-131, using techniques outlined in the RSS filmstrips, should enable most teachers to gain the necessary experience for safe handling of these materials.

Many individuals also have the mistaken notion that minors cannot handle radioactive material without receiving an undue radiation hazard, or that minors must follow the 5 (N-18) age rule set for occupational workers. Actually, according to 25 FR 10914, Sec. 20.101 of AEC Rules, minors may not receive more than 10% of the adult dose of 1.25 rem or 1250 mrem, which is 125 mrem per calendar quarter for minors. The staff members of the Radiation Science Seminar, in all the years' experimentation with license-exempt (general license) quantities, have never received any radiation dose measurable upon a film badge or dosimeter. Thus no significant radiation hazard exists with license-exempt radioisotopes. If radioisotopes are treated with the care and respect accorded to chemicals such as H_2SO_4 and KCL_3, any radiation hazard will be minimal. Certain pertinent parts of the AEC Rules have been reproduced here for those desiring the exact wording of the regulations.

LICENSE EXEMPT QUANTITIES OF RADIOISOTOPES

Title 10 Part 31.4 AEC Regulations

Byproduct material	Column No. I Not as a sealed source (microcuries)	Column No. II As a sealed source (microcuries)
124 Antimony	1	10
76 Arsenic	10	10
77 Arsenic	10	10
140 Barium—140 Lanthanum	1	10
7 Beryllium	50	50
109 Cadmium—109 Silver	10	10
45 Calcium	10	10
14 Carbon	50	50
144 Cerium—Praseodymium	1	10
137 Cesium—137 Barium	1	10
36 Chlorine	1	10
51 Chromium	50	50
60 Cobalt	1	10
64 Copper	50	50
154 Europium	1	10
18 Fluorine	50	50
72 Gallium	10	10
71 Germanium	50	50
198 Gold	10	10
199 Gold	10	10
3 Hydrogen (Tritium)	250	250
114 Indium	1	10
131 Iodine	10	10
192 Iridium	10	10
55 Iron	50	50
59 Iron	1	10
140 Lanthanum	10	10
52 Manganese	1	10
56 Manganese	50	50
99 Molybdenum	10	10
59 Nickel	1	10
63 Nickel	1	10
95 Niobium	10	10
109 Palladium	10	10
103 Palladium—103 Rhodium	50	50

Byproduct material	Column No. I Not as a sealed source (microcuries)	Column No. II As a sealed source (microcuries)
32 Phosphorus	10	10
210 Polonium	0.1	1
42 Potassium	10	10
143 Praseodymium	10	10
147 Promethium	10	10
186 Rhenium	10	10
105 Rhodium	10	10
86 Rubidium	10	10
106 Ruthenium—106 Rhodium	1	10
153 Samarium	10	10
46 Scandium	1	10
105 Silver	1	10
111 Silver	10	10
22 Sodium	10	10
24 Sodium	10	10
89 Strontium	1	10
90 Strontium—90 Yttrium	0.1	1
35 Sulfur	50	50
182 Tantalum	10	10
96 Technetium	1	10
99 Technetium	1	10
127 Tellurium	10	10
129 Tellurium	1	10
204 Thallium	50	50
113 Tin	10	10
185 Tungsten	10	10
48 Vanadium	1	10
90 Yttrium	1	10
91 Yttrium	1	10
65 Zinc	10	10
Beta and/or Gamma emitting by-product material not listed above	1	10

PART 20

STANDARDS FOR PROTECTION AGAINST RADIATION

*Added 25 FR 13952

25 FR 10914

GENERAL PROVISIONS

§ 20.1 Purpose.

(a) The regulations in this part establish standards for protection against radiation hazards arising out of activities under licenses issued by the Atomic Energy Commission and are issued pursuant to the Atomic Energy Act of 1954 (68 Stat. 919).

(b) The use of radioactive material or other sources of radiation not licensed by the Commission is not subject to the regulations in this part. However, it is the purpose of the regulations in this part to control the possession, use, and transfer of licensed material by any licensee in such a manner that exposure to such material and to radiation from such material, when added to exposures to unlicensed radioactive material and to other unlicensed sources of radiation in the possession of the licensee, and to radiation therefrom, does not exceed the standards of radiation protection prescribed in the regulations in this part.

§ 20.2 Scope.

The regulations in this part apply to all persons who receive, possess, use or transfer byproduct material, source material, or special nuclear material under a general or specific license issued by the Commission pursuant to the regulations in Part 30, 40, or 70 of this chapter.

§ 20.3 Definitions.

(a) As used in this part:

(1) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto;

(2) "Airborne radioactive material" means any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases;

(3) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

(4) "Calendar quarter" means any period determined according to either of the following subdivisions:

§ 20.4 Units of radiation dose.

25 FR 10914

(a) "Dose," as used in this part, is the quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body. When the regulations in this part specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in this part are set forth in paragraphs (b) and (c) of this section.

(b) The rad, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad (mrad) = 0.001 rad.)

(c) The rem, as used in this part, is a measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen (r) of X-rays. (One millirem (mrem) = 0.001 rem.) The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions of irradiation. For the purpose of the regulations in this part, any of the following is considered to be equivalent to a dose of one rem:

(1) A dose of 1 r due to X— or gamma radiation;

(2) A dose of 1 rad due to X—, gamma, or beta radiation;

(3) A dose of 0.1 rad due to neutrons or high energy protons;

(4) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye;

If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in subparagraph (3) of this paragraph, one rem of neutron radiation may, for purposes of the regulations in this part, be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there exists sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to one rem may be estimated from the following table:

NEUTRON FLUX DOSE EQUIVALENTS

Neutron energy (Mev)	Number of neutrons per square centimeter equivalent to a dose of 1 rem (neutrons/cm²)	Average flux to deliver 100 millirem in 40 hours (neutrons/cm² per sec.)
Thermal	970×10^6	670
0.0001	720×10^6	500
0.005	820×10^6	570
0.02	400×10^6	280
0.1	120×10^6	80
0.5	43×10^6	30
1.0	26×10^6	18
2.5	29×10^6	20
5.0	26×10^6	18
7.5	24×10^6	17
10	24×10^6	17
10 to 30	14×10^6	10

(d) For determining exposures to X or gamma rays up to 3 Mev, the dose limits specified in §§ 20.101 to 20.104, inclusive, may be assumed to be equivalent to the "air dose". For the purpose of this part "air dose" means that the dose is measured by a properly calibrated appropriate instrument in air at or near the body surface in the region of highest dosage rate.

§ 20.5 Units of radioactivity.

(a) Radioactivity is commonly, and for purposes of the regulations in this part shall be, measured in terms of disintegrations per unit time or in curies. One curie (c) $= 3.7 \times 10^{10}$ disintegrations per second (dps) $= 2.2 \times 10^{12}$ disintegrations per minute (dpm). A commonly used submultiple of the curie is the microcurie (μc). One $\mu c = 0.000001$ c $= 3.7 \times 10^4$ dps $= 2.2 \times 10^6$ dpm.

§ 20.7 Communications.

31 FR 4668

Except where otherwise specified in this part, all communications and reports concerning the regulations in this part, and applications filed under them, should be addressed to the Director of Regulation, U.S. Atomic Energy Commission, Washington, D.C., 20545. Communications, reports and applications may be delivered in person at the Commission's offices at 1717 H Street NW., Washington, D.C.; at 4915 St. Elmo Avenue, Bethesda, Md.; or at Germantown, Md.;

§ 20.101 Exposure of individuals to radiation in restricted areas.

25 FR 10914

(a) Except as provided in paragraph (b) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual in a restricted area to receive in any period of one calendar quarter from radioactive material and other sources of radiation in the licensee's possession a dose in excess of the limits specified in the following table:

Rems per calendar quarter

1. Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	1¼
2. Hands and forearms; feet and ankles	18¾
3. Skin of whole body	7½

(b) A licensee may permit an individual in a restricted area to receive a dose to the whole body greater than that permitted under paragraph (a) of this section, provided:

(1) During any calendar quarter the dose to the whole body from radioactive material and other sources of radiation in the licensee's possession shall not exceed 3 rems; and

(2) The dose to the whole body, when added to the accumulated occupational dose to the whole body, shall not exceed 5 (N−18) rems where "N" equals the individual's age in years at his last birthday; and

§ 20.104 Exposure of minors.

25 FR 10914

(a) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area who is under 18 years of age, to receive in any period of one calendar quarter from radioactive material and other sources of radiation in the licensee's possession a dose in excess of 10 percent of the limits specified in the table in paragraph (a) of § 20.101.

(b) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area, who is under 18 years of age to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table II of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than a week.

(c) The provisions of paragraph (c) of § 20.103, shall apply to exposures subject to paragraph (b) of this section.

§ 20.204 Exceptions from posting requirements.

Notwithstanding the provisions of § 20.203,

(a) A room or area is not required to be posted with a caution sign because of the presence of a sealed source provided the radiation level twelve inches from the surface of the source container or housing does not exceed five millirem per hour.

31 FR 10314

(d) A room or other area is not required to be posted with a caution sign because of the presence of radioactive materials packaged and labeled in accordance with regulations of the Interstate Commerce Commission, Federal Aviation Agency, or Coast Guard.

§ 20.207 Storage of licensed materials.

Licensed materials stored in an unrestricted area shall be secured against unauthorized removal from the place of storage.

WASTE DISPOSAL

§ 20.301 General requirement.

No licensee shall dispose of licensed material except:

(a) By transfer to an authorized recipient as provided in the regulations in Part 30, 40, or 70 of this chapter, whichever may be applicable; or

(b) As authorized pursuant to § 20.302; or

(c) As provided in § 20.303 or § 20.304, applicable respectively to the disposal of licensed material by release into sanitary sewerage systems or burial in soil, or in § 20.106 (Concentrations in Effluents to Unrestricted Areas).

25 FR 10914

§ 20.303 Disposal by release into sanitary sewerage systems.

No licensee shall discharge licensed material into a sanitary sewerage system unless:

(a) It is readily soluble or dispersible in water; and

(b) The quantity of any licensed or other radioactive material released into the system by the licensee in any one day does not exceed the larger of subparagraphs (1) or (2) of this paragraph:

(1) The quantity which, if diluted by the average daily quantity of sewage released into the sewer by the licensee, will result in an average concentration equal to the limits specified in Appendix B, Table I, Column 2 of this part; or

(2) Ten times the quantity of such material specified in Appendix C of this part; and

(c) The quantity of any licensed or other radioactive material released in any one month, if diluted by the average monthly quantity of water released by the licensee, will not result in an average concentration exceeding the limits specified in Appendix B, Table I, Column 2 of this part; and

(d) The gross quantity of licensed and other radioactive material released into the sewerage system by the licensee does not exceed one curie per year.

25 FR 10914

Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section.

§ 20.304 Disposal by burial in soil.

No licensee shall dispose of licensed material by burial in soil unless:

(a) The total quantity of licensed and other radioactive materials buried at any one location and time does not exceed, at the time of burial, 1,000 times the amount specified in Appendix C of this part; and

(b) Burial is at a minimum depth of four feet; and

(c) Successive burials are separated by distances of at least six feet and not more than 12 burials are made in any year.

§ 20.305 Treatment or disposal by incineration.

No licensee shall treat or dispose of licensed material by incineration except as specifically approved by the Commission pursuant to §§ 20.106(b) and 20.302.

The Safe Use of Radioisotopes

by

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J. M. Coughlin High School
Wilkes-Barre, Pa.

THE TWO GUIDELINES to be observed when working with radioactive materials are *care* and *common sense*. Radioactive materials, when treated with respect, not fear, are just as safe and sometimes even safer than some of the chemicals we have come to accept as part of our lab routine. Potassium chlorate, for example, may be more dangerous if handled improperly than license-exempt quantities of radioisotopes such as phosphorus-32.

Yet there exists an inherent fear of radioactivity among students and some teachers. Many people working with radioisotopes for the first time seem to be terrified of the fact that a radioactive material is under their control. I remember quite vividly one boy who was preparing a radioactive source for the first time. His hands actually shook as he manipulated the micropipette control. The result was inevitable—spillage.

No damage was done because the work was being performed over a tray lined with absorbent paper. If this boy had thought of the radioisotope as just another laboratory chemical requiring care and respect, the spill would never have occurred. The same boy, incidentally, handles strong acids and other potentially dangerous reagents with no difficulty whatsoever.

Unjustified Apprehension

Such fears are unjustified when one considers the amounts of radioactive materials available to the high school without a specific license. The Atomic Energy Commission allows a laboratory or individual to possess up to ten radioactive sources, called exempt quantities. Commercial suppliers of radioactive materials publish brochures which explain the quantities available.

Those radioisotopes popular in educational work on the tracer level are shown in Table 1. A laboratory may possess up to ten such exempt quantities at one time. This means, for example, that the laboratory may possess ten separate bottles of any of the radioisotopes shown in the table. It also means that the laboratory may possess up to ten separate bottles of the same radioisotope at the same time. The ten bottles of the same radioisotope may not be mixed, though, since this is illegal.

Note that a *possession limit* exists; no restriction limits the number of such scheduled quantities used in the course of a year, as long as *a maximum of ten are present at any one time.*

More and more states are entering into agreements with the AEC in which the AEC relinquishes control to the state. About a dozen states have done so already, and more are expected to follow suit. In some cases, the states may prescribe lesser quantities of certain radioisotopes for license-free use.

The AEC licenses "by-product" material—material produced in a reactor. Naturally, radioactive materials such as uranium, thorium, and radium salts are not considered by-product material. Nevertheless, some states prescribe limits where the AEC does not, especially for radium salts. It is wise to check with the nearest state health department to see if such agreements exist. If short-lived materials, e.g., P^{32} and I^{131}, are used, the state limits are usually the same as the federal.

Work Areas and Sources

The selection of a radioisotope work area should be made with some care. If at all possible, the sample preparation area should be divorced from the counting area to avoid a high background count, which may introduce serious errors in the experimental results.

Ideally, the sample preparation area should be in a separate room from the counting area. In most laboratories this is not possible. If the two areas must be in the same room, keep them on opposite sides of the room. If this is not possible, and the two areas are on the same table, place a shield of inch-thick wood or ordinary house bricks between them.

Because the actual mass of a license-free radiochemical is so small—on the microgram level—radiochemicals are usually supplied in aqueous solution in high or low specific activity. Ten microcuries of I^{131} in 0.5 ml of solution would be of high specific activity, while the same amount in 5 or 10 ml of solution would be of low specific activity.

High specific activities are useful, but micro apparatus must be used for dispensing these small volumes. Micropipettes of the Lang-Levy type are popular in conjunction with the Clay-Adams micropipette control. The micropipette control may be easily manipulated with the right hand; the volume of liquid admitted or expelled is easily controlled by merely twisting the screw at the top with the thumb and index finger. See Fig. 1.

Low specific activity solutions, in the 5-ml range, are dispensed easily with an ordinary laboratory pipette and a remote-control device called the "Propipettor." The "Propipettor" is merely a hollow rubber sphere with an ingenious set of ball valves that regulate the amount of air admitted to a pipette. If only approximate volumes are needed, an ordinary medicine-dropper pipette will suffice. Fancy remote-control apparatus, such as tongs, pipetters, and slave units are totally unnecessary with license-exempt quantities.

Under no circumstances should any radioactive liquids be pipetted by mouth. Nor should any radioactive material be placed in the mouth. Of course, this also holds for all ordinary laboratory chemicals.

It goes without saying that eating, drinking, and applying cosmetics are absolutely forbidden in radioisotope laboratories, just as they are in most other laboratories.

Handling Radioisotopes

Sealed radioactive sources, as supplied by all manufacturers, are quite safe to handle since AEC regulations are very stringent for sealed sources. All open radioactive liquids, however, should be handled over a tray lined with absorbent paper (see Fig. 2) to minimize contamination of the workbench in case of a spill. It is a good idea to line the work area

tabletop also. A layer of newspaper taped to a layer of waxed paper underneath makes an effective absorbent lining in case of spills.

Spills should be wiped immediately with absorbent paper (wear rubber gloves). Tissue, paper towels, photographic blotter paper, and newspapers are excellent absorbent papers. The wet paper should be placed in the container specified for radioactive waste disposal.

Most workers prefer to wear thin rubber surgeon's gloves while handling radioactive liquids. It is much easier to decontaminate a rubber glove than a human hand. The gloves may feel uncomfortable at first, especially if no talcum powder has been added to the inside to prevent perspiring. After a few minutes of wear, manual dexterity usually returns.

Rubber gloves are worn only for preparative work. They are rarely used when counting samples in order to prevent contamination of counting equipment.

The gloves should be monitored by another person for contamination *while they are still on the hands.* It is simpler to wash the hands with the gloves still on rather than the gloves themselves if radioactive liquids are accidentally spilled.

Quite often samples are prepared for counting by adding the reaction system to a small shallow cup called a planchet. Planchets with concentric raised rings are popular because the liquid system can be kept in the center easily. These planchets can be handled safely with ordinary small laboratory forceps or with special planchet forceps.

After a planchet has been dried, and is ready for counting, it is sometimes a good idea to spray it with a transparent plastic. This prevents metal from flaking off the planchet. It also prevents volatilization of the radioactive compound, which may occur upon occasion. Transparent lacquers such as Krylon serve very well and may be purchased in convenient spray cans. Do not use such a spray on an alpha-emitter because the short-range alpha particles cannot penetrate the coating.

If radioisotopes are being used in experiments with animals, such as mice, rats, and rabbits, the animals should be adequately anesthetized at the time of injection. An animal resisting injection can sometimes cause widespread contamination. Animals should be injected over the paper-lined tray mentioned earlier. Disposable syringes are best used, as they may be discarded with the other waste.

The animals themselves, once injected or fed radioactive material, must be kept in a securely locked, labelled cage that has been lined with absorbent paper to catch the excreta, which may be radioactive. All such paper linings and excreta should be discarded with other waste in the designated waste receptacle.

Most radioisotopes are supplied in stable chemical forms. Nevertheless, two radioisotope solutions may present an airborne radioactivity hazard if added to acids. Iodine-131, commonly supplied as sodium radioiodide, and carbon-14, commonly supplied as sodium or barium radiocarbonate, will form radioactive vapor and radiocarbon dioxide respectively if acid is added to the solution. The solution to this problem is simple—keep all acids away from I^{131} and C^{14} solutions or else use under a hood in good working order. This latter precaution should be taken whenever a radioactive gaseous byproduct is expected.

Before leaving the laboratory after radioactive materials have been used, the work area, the hands, and the clothing should be monitored for contamination with a Geiger counter. With the instrument set on its lowest scale, the probe should be moved slowly over the suspected area as close as possible without actually touching it. If the instrument has a time constant switch, set it at "SHORT" for monitoring. ***Any count above normal background should be interpreted as evidence of contamination.***

The detector used for monitoring should match the radiation given off by the suspected contaminant. All Geiger counters will not detect all types of radiation, nor radiation of certain energies. For example, the common CD V-700 instrument supplied to most public high schools by Civil Defense will not detect alpha particles or soft (weak) beta radiation because the tube thickness is so great the particles cannot penetrate the tube wall. The weak beta radiation emitted by carbon-14 (0.154 Mev) and sulfur-35 (0.167 Mev) can be detected easily with a thin end-window Geiger tube of 1.4-3.0 mg/cm² density thickness, but not with the thicker side-window Geiger tube of 30 mg/cm² density thickness, as found on the V-700 apparatus.

It is good practice to segregate glassware being used with radioactive materials. A small dab of paint or nail polish may be used to identify such glassware. AEC-approved warning labels should be affixed to glassware containing radioactive material. The label should contain the kind of radioisotope inside, the amount of radioactivity in microcuries or counts

TABLE 1. POPULAR RADIOISOTOPES

RADIOISOTOPE AND TYPES OF RADIATION	LICENSE-EXEMPT QUANTITY MICROCURIES LIQUID	SEALED	HALF-LIFE
Carbon-14 (β)	50	50	5700 yrs
Cesium-137 (β, γ)	1	10	30 yrs
Chromium-51 (γ)	50	50	27 days
Cobalt-60 (β, γ)	1	10	5.2 yrs
Iodine-131 (β, γ)	10	10	8.1 days
*Lead-210, RaDEF (α, β, γ)	....	....	22 yrs
Phosphorus-32 (β)	10	10	14.3 days
Polonium-210 (α)	0.1	1	138 days
Sodium-22 (β^+, γ)	10	10	2.6 yrs
Thallium-204 (β)	50	50	4 yrs
†Uranium nitrate U-238 (α, β, γ)	....	....	4.5×10^9 yrs

*Also natural product, but state laws vary. Available from 0.1 μc to 5 μc depending upon supplier.
†Natural product, no limitation of consequence unless state law to contrary.

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per minute, and the date of preparation. Homemade labels are not adequate. The cost of approved labels, however, is quite low.

After glassware has been used with radioactive material, it must be decontaminated before being used again. Decontamination may be accomplished by scrubbing with a powerful laboratory detergent such as Sparkleen, Alconox, Radiac-wash, or even common household Tide. Rubber gloves are recommended during decontamination procedures, but remember to use plenty of running water as a rinse.

When dry, the glassware should be monitored with a Geiger counter to see if any radioactivity remains. If the item shows a count no higher than background (about 30-40 cpm in most laboratories) it is considered decontaminated.

Occasionally, a piece of glassware may prove difficult to decontaminate with detergent. A few days soak in the old reliable chromic acid bath (100 g of $K_2Cr_2O_7$ and 400 ml of conc. H_2SO_4 in 600 ml water) should remove any remaining radioactivity. If the item is still contaminated after a few such acid baths, throw it away.

Waste Disposal

All material which cannot be decontaminated, such as the paper used in trays, disposable syringes, solid waste, plastic spatulas, etc., should be placed in a storage can lined with paper and specifically marked for disposal of radioactive materials. It is not good practice to keep too much radioactive waste in storage. As often as possible, the waste should be incinerated or otherwise disposed of. If an incinerator is not available, the radioactive waste may be discarded in small quantities along with ordinary lab refuse.

Repeated scrubbings with a strong cleanser will usually remove contamination from workbenches, floors, and other surfaces.

One laboratory sink, preferably one seldom used, should be designated as a "hot sink" for disposal of radioactive wastes and rinsings. This prevents needless contamination of all laboratory sinks. The sink in the teacher's demonstration hood is ideal for this purpose since it is seldom used by pupils.

Waste disposal presents no great problem. The public sewers may be used for disposal of materials of short half-life, such as I^{131} and P^{32}, if the radioactive liquid is flushed down the laboratory sink with plenty of water. Radioisotopes of longer half-life than I^{131} and P^{32} should be held for decay if possible and then flushed down the sewer with plenty of water. If the school is situated in a suburban area and has its own septic tank system or sewage disposal system, radioisotopes should never be flushed down the drain. Instead, the waste should be kept in a large, widemouthed bottle and then incinerated, or discarded with other lab refuse.

Although perfectly proper, it is not a good idea to dispose of waste in *marked* cans and bottles along with the normal laboratory refuse. Refuse collectors become highly excited when they see radioactive warning labels.

Radioactive sources and liquids should be kept segregated in a small box or cabinet that can be locked securely. This keeps them away from the curious and forestalls frightening the cleaning and maintenance people.

Thick shielding such as lead is also unnecessary with license-exempt quantities. A small plastic box, such as a fisherman's fly box, or a small tin can will provide adequate shielding for most sources. If lead shields are desired for storage, they can be purchased or secured gratis from the radioisotope lab of a local hospital.

Badges and Dosimeters

Persons who handle larger quantities of radioisotopes than license-exempt quantities, and for longer periods of time, must carry a ***film badge*** and ***pocket dosimeter*** in order to determine their cumulative dose and daily dose. The amount of radiation emitted by license-exempt quantities, however, does not necessitate the wearing of a film badge or a dosimeter. In fact, the dosimeters provided by Civil Defense and found in almost every public high school are almost useless with license-exempt quantities. Any movement of the reticle on a Civil Defense dosimeter—even the lowest scale range, 0-200 mr—is due to leakage of the charge on the dosimeter rather than any radiation from license-exempt sources. These dosimeters are sensitive to gamma and x-radiation only, so they are of no value when alpha and beta-emitters are handled.

When fear or carelessness prevail, the use of radioisotopes creates problems. When care and common sense are the watchwords, they become an extremely useful tool in the hands of the experimenter. Radioisotopes are widely used in all areas of science. Hence they have value for all science teachers. It is a mistake to exclude them from the classroom on the grounds of fear or apprehension. They are no more dangerous than many other chemical reagents now in wide use.

NUCLEAR SCIENCE SYLLABUS

THE NUCLEAR SCIENCE LABORATORY SEQUENCE

The ideal aim of every teacher of a laboratory-oriented course is to have each laboratory lesson precede the lecture. In this way the discovery method is more valid. However, in the nuclear science program shown here, it is not possible to correlate completely the laboratory program and the lecture program for all units.

The instructor has his choice of two methods of attaching the integration of the lab program:

(a) follow the sequence given under learning experiences, which allows more correlation after the first unit;
(b) follow the core sequence given

The RSS staff prefers the sequence favored by Chase et al and Hermias et al in which the first part is devoted to nuclear lab fundamentals and the later parts are devoted to nuclear experiments in biology, chemistry, physics, and general applications.

These laboratory texts are the only two suitables for high school use because of their format and mode of treatment. Although many other manuals exist containing excellent nuclear experiments, for the most part these manuals are designed as teacher reference books from which experiments may be adopted.

Drying samples under a heat lamp.

These students examine a neutron howitzer during a fieldtrip to the radiochemical labs at Phila. College of Pharmacy & Science.

SUGGESTED BASIC EXPERIMENTS FOR A ONE-SEMESTER COURSE IN NUCLEAR SCIENCE

Personal Monitoring Devices (Po^{210} 0.1 uc, Tl^{204})
Survey Meters 0.5 uc, (Co^{60} 0.5 uc)
Sample Preparation (Cs^{137}, 0.1 uc)

Plotting a Geiger Plateau (Cs^{137} 0.1 uc)
Background no sources
Resolving time (Cl^{36} 0.1 uc)
Changes in Instrument Efficiency (Cs^{137} 0.1 uc)

Shelf Ratios (Tl^{204} 0.1 uc)
Absorption of Radiation by Sample I (U^{238} 20% sol)
Absorption of Radiation by Sample II
Absorption of Radiation by Sample III

Randomness of Disintegration no source
Half-life (Ga^{68} 0.1 uc)

DEMONSTRATIONS AS PART OF LECTURES

Backscattering
Sidescattering (Tl^{204} 0.1 uc; Sr^{90} 0.1 uc (both sealed)
Cloud Chambers
Deflection of Beta Particles by a Magnetic Field (P^{32} 0.1 uc)

NUCLEAR DETECTION

Ionization Chambers (C^{14} 0.5 uc)
Autoradiography (P^{32} 10 uc)

NUCLEAR BIOLOGY

Absorption of Phosphorus by Frogs (P^{32} 10 uc)

NUCLEAR PHYSICS

Range of Alpha Particles (Po^{210} 0.1 uc)

NUCLEAR CHEMISTRY

Separation by Paper Chromatography (Pb^{210} 0.1uc)

NUCLEAR INDUSTRIAL APPLICATIONS

Detergent Efficiency (P^{32} 10 uc)

NUCLEAR BIOLOGY

Absorption of Phosphate by a Plant (P^{32} 10 uc)
Distribution of Phosphate in a Plant (P^{32} 10 uc)
Non-root Feeding of Plants (P^{32} 10 uc)

NUCLEAR PHYSICS

Inverse Square Law (Ra^{226} Sealed, 15 ug)
Beta Decay Energy (Tl^{204} 0.1 uc or Cl^{36} 0.1 uc)

NUCLEAR CHEMISTRY

Separation by Precipitation (U^{238})
Separation by Solvent Extraction (U^{238})

NUCLEAR INDUSTRIAL APPLICATIONS

Thickness Gauging (Sr^{90} 0.1 uc)
Depth Gauging (Co^{60} 0.1 uc)
Wear Testing (Ga^{68} 1uc)

CONTENT	LEARNING EXPERIENCES
1. STRUCTURE OF MATTER A. Historical Development 1. Early Atomic Theories 2. Discovery of Sub-atomic particles 3. Discovery of X-rays 4. Radioactivity 5. Later Atomic Models a. Thomson b. Rutherford c. Bohr d. Schrodinger B. Particles and Waves 1. Classification a. Leptons b. Mesons c. Nucleons d. Hyperons 2. Properties of Nucleons a. Protons b. Neutrons c. Electrons d. $A = Z + N$ 3. Dualism of Matter a. DeBroglie Equation b. Application of DeBroglie Theory to Atom	1. Discuss how early theories were revived, expanded and accepted. 2. Demonstrate Crookes tube and discharge through gases. 3. LABORATORY EXPERIMENTS a. Personal Monitoring Devices (Electroscope, dosemeter, film badge) Chase et al, pages 1-2 Hermeas and Joecile, pages 31, 44 b. Survey Meters Chase et al, page 3

TEXT REFERENCES

Overman pp.

Harvey pp. 1-4

Choppin pp. 1-4

Dance pp. 1-4

AUDIO-VISUAL AIDS

Handle with care: The safe handling of Radioisotopes (1963). 21½ Min. B & W

This semitechnical training film, for audiences of high school level and above, covers some of the methods of safe handling of radioisotopes in a laboratory and points out the procedures followed by laboratory personnel to avoid contamination. While the film is instructional in nature, its content is presented in the form of a story of an unlikely, but possible, contamination incident. Told via the flashback technique, the story involves the happenings of one afternoon in a laboratory as a scientist goes about his work in an apparently methodical and routine manner. As he recalls the happenings of the day, the audience sees in detail all the procedures used in the safe handling of radioisotopes. The mystery of the contamination is solved at the end of the film. The film shows the use of protective clothing, radiation measuring devices such as film badges, dosimeters and counters, the handling of the radioisotopes in an experiment using a fume hood, and clean-up procedures following an experiment.

AUDIO-VISUAL AIDS

DISCHARGE THROUGH GASES
12 Min. B & W, McGraw-Hill 603504

A film demonstration of the discharge patterns which occur when pressure is progressively reduced as well as a clear explanation of the theory of discharge through rarefied gases.

THE STRUCTURE OF ATOMS
12½ Min. color, McGraw-Hill, 612024

This film provides the experimental evidence for our basic concepts concerning the structure of the atom. An experiment similar to Rutherford's historic alpha particle scattering demonstrations shows that atoms have dense, positively charged nuclei. Another fundamental experiment shows the charge on the electron and the ratio of charge to mass.

COSMIC RAYS
27 Min. color, McGraw-Hill 681122

A detailed examination of present concepts of the origin and nature of charged particles reaching the earth from outer space. Recent discoveries -- using balloons, rockets and satellites -- are presented. The relationship between cosmic ray research and nuclear research is outlined.

CONTENT	LEARNING EXPERIENCES
C. Atomic Structure 1. Atomic Properties 2. Atomic Dimensions	1. Students who have not been exposed to PSSC experiment, measuring length of stearic or oleic acid, may be given this experiment to show how scientists secure indirect measurements.
3. The Bohr Model a. Postulates of Bohr Theory b. Calculations 1. Orbit radii 2. Electron velocity 3. Energy relationships	2. Assign problems from 3b.
4. The Schrodinger Model a. Postulates of the Theory b. Comparison to Bohr Model c. Pauli Exelusion Principle	3. Show Aufbau principle with overhead projector and transparencies.
5. Electron Configurations a. Pauli Exclusion Principle b. Heisenberg Uncertainty Principle c. Aufbau d. Electron Configuration and Periodic Law	4. Have students practice electron configuration using Fisher-Cook Atomic Orbital Board. 5. LABORATORY EXPERIMENTS Sample Preparation (using micro and macro pipette controls, liquids and solids) Chase et al pp. 6-8 Hermias & Joecile pp.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 1-8 Harvey pp. 4-6 Choppin pp. Dance pp.	A - ATOMIC PHYSICS (1948) 90 minutes, black and white This file discusses the history and development of atomic energy, stressing nuclear physics, Dalton's basic atomic theory, Faraday early experiments in electrolysis, Mendeleev's periodic table, and early concepts and size of atoms and molecules are discussed also. The film demonstrates how cathode rays were investigated and how the electron was discovered; how the nature of positive rays was established; and how X-rays were found and put to use. The film also presents research tools of nuclear physics, explains work of Joliot-Curie and Chadwick in discovery of neutron, and splitting of lithium atom by Cockcroft and Walton. Einstein tells how their work illustrates his theory of equivalence of mass and energy. Uranium fission is explained, as well as why it is possible to make an atomic bomb. FOM - 616 Filmstrip Atomic Structure and Chemistry A - A IS FOR THE ATOM (1964) 14 minutes, color This non-technical, fully animated film, for elementary through high school level audiences, explains the structure of the atom using an analogy to the solar system, discusses natural elements and artifically produced elements showing how they are identified by number, describes stable and unstable atoms, and tells of the discovery of nuclear fission. Well done. RSS #1 Filmstrip "Sample Preparation"

CONTENT	LEARNING EXPERIENCES
2. NATURE OF THE ATOMIC NUCLEUS A. NUCLEAR STRUCTURE 1. Early Theories 2. Nuclear Forces 3. Liquid Drop Model 4. Shell Model a. n-p ratios b. Magic number rules c. Nucleon pairing 5. Comparison of Both Models - Collective Model	1. LABORATORY EXPERIMENT a. <u>Plotting a Geiger Plateau</u> Chase et al pp. 9 Hermias & Joecile pp. 47 b. <u>Background</u> Chase et al pp. 13 Hermias & Joecile pp.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 8-18 Harvey pp. 33-42; 19-32 Choppin pp. 4-16; 95-96; 62-89 Dance pp.	PRINCIPLES OF NUCLEAR FISSION 10 min. Color, McGraw-Hill 603511 After considering the historic and the modern conceptions of the structure of the atom, the film shows diagrammatically the relation of its basic particles, electrons, protons, and neutrons. It describes in detail how bombarding neutrons cause fission in Uranium-235 atoms and the production of chain reactions. The film then deals with the graphite nuclear reactor, showing methods of controlling action in a nuclear reactor and relating this to the production of electricity. ISOTOPES 15 min. Color, McGraw-Hill 603517 The film shows uranium being separated into two isotopes -- U-238 and U-235. It explains how J. J. Thompson first demonstrated the existence of isotopes and how Aston developed the first mass spectrometer. It then shows two methods of separating isotopes and concludes by illustrating the uses of radioisotopes.

CONTENT	LEARNING EXPERIENCES
B. NUCLEAR STABILITY 1. Stability Diagonal 2. Neutron/Proton Ratios a. Low b. High 3. Magic Number Rules a. Even Z, more stable b. Even N, more stable c. Even A, more stable d. Even A and even Z, more stable 4. Binding Energy	1. Have students predict stability of nuclides using criteria at left. 2. LABORATORY EXPERIMENT: <u>Resolving Time</u> Chase et al pp. 15 Hermias & Joecile pp. <u>Changes in Instrument Efficiency</u> Chase et al pp. 19 Hermias & Joecile pp. 51

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. Harvey pp. 62; 30; 31-16 Choppin pp. 95; 8-10; 93; 144; 17-20 Dance pp.	

CONTENT	LEARNING EXPERIENCES
C. NUCLEAR EQUATIONS 1. Conservation of mass principle 2. Balancing Nuclear Equations a. Review of particle symbols b. Balancing technique 3. Shorthand notation a. Differences in symbols b. Technique	1. Have students balance nuclear equations. "Dictionary of Chemical Equations", (Eclectic Publ. Co.) has many examples from which to choose. 2. LABORATORY EXPERIMENTS: <u>Shelf Ratios</u> Chase et al pp. 21 Hermias & Joecile pp. 70 <u>Absorption of Radiation by Sample</u> Chase et al pp. 32-40 Hermias & Joecile pp.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 24-27 Harvey pp. Choppin pp. 96-102 Dance pp.	FUNDAMENTALS OF RADIOACTIVITY (PMF-5145-A). 59 minutes This film traces uranium from prospector to the USAEC. It shows how uranium changes into other elements through radioactive decay and through nuclear fission. Mention is made of Einstein's equation $E = mc^2$, the atomic bomb, and use of nuclear power for industry. Stable and radioactive isotopes are explained, with isotope charts and energy level diagrams used to illustrate decay. Various radiations resulting from nuclear changes are described in detail. The nuclear reactor is described in terms of fission and moderation. Also shown are target materials introduced into a typical nuclear reactor and withdrawn as radioisotopes and the processing of fission products. More than fifty terms and concepts are defined and explained. THE PETRIFIED RIVER (1956) 28 minutes, Color This nontechnical film for all audience levels describes how uranium was deposited during prehistoric, geologic ages; prospecting on the Colorado Plateau; mining and milling of uranium ores; and the use of the atom's energy for power and to produce radioisotopes for medical diagnosis and therapy, agriculture, industry and research.

CONTENT	LEARNING EXPERIENCES
D. NUCLEAR ENERGY 1. Mass Units 2. Conservation of Mass-Energy a. The Einstein Equation b. Exoergic Reactions c. Endoergic Reactions	1. Assign problems dealing with mass-energy relationships. 2. Discuss how nuclear energy may be used for man's benefit or man's destruction.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 12-13 Harvey pp. 16;59 Choppin pp. 103-106 Dance pp.	TALE OF TWO CITIES 17 min. B & W This film depicts the destruction of Hiroshima and Nagasaki in 1945. Although a Civil Defense film, it illustrates the tremendous energy release from a nuclear reaction in a most vivid manner. OPERATION CUE 14 min. Color The 1955 Nevada Atomic Test is told by a newspaper-woman invited to observe the test, this story follows from preparatory stages through the day following the shot. This film underscores the fact that such nuclear tests, arranged by the Atomic Energy Commission in cooperation with the FCDA. are essential in providing information as to weapons effects, thus contributing to national survival under nuclear attack. It also shows the huge energy release of atomic weapons. NUCLEAR REACTOR 9 min. B & W, McGraw-Hill 638002 Starting with a discussion of nuclear stability and neutron-induced fission, the film develops the ideas of neutron emission, the self-sustaining chain reaction, and the role of the moderator. It then illustrates the application of these ideas to the pile. The production of plutonium and of tracer elements is discussed.

CONTENT	LEARNING EXPERIENCES
E. NUCLEAR REACTIONS 1. General Classification a. Natural reactions b. Induced reactions 2. Fission 3. Fusion 4. Radioactive Decay 5. Transmutation 6. Activation	LABORATORY EXPERIMENT OR DEMONSTRATION: 1. Randomness of Disintegration: Chase et al pp. 43 Hermias & Joecile pp. 2. Cloud Chambers Chase et al pp. 64 Hermias & Joecile pp. 35 The cloud chamber and photographs from cloud chambers can be used to show how nuclear reactions are investigated. At times, certain elementary nuclear reactions may be seen, with different impinging and resultant rays.

TEXT REFERENCES

Overman pp. 24-27; 95-97

Harvey pp. 57-68; 87-101

Choppin pp. 103-106; 106-112

Dance pp.

AUDIO-VISUAL AIDS

A - OF MAN AND MATTER
(1963) 29 min. Color

This film describes the design, development and operation of the alternating gradient synchrotron (AGS) at Brookhaven National Laboratory, shows the various major components of this 33 billion-electron-volt particle accelerator, and explains how the high energy protons produced in the machine are used in physical research. An actual experiment is seen, in which the particle beam is guided into a bubble chamber and the resultant interactions with the target nuclei are photographed. The methods adopted in scanning and analyzing the photographs are also shown. By means of a brief lecture, a Brookhaven physicist explains that such gigantic and complex machines as the AGS are necessary in order to study the fundamental particles and the forces within the atomic nucleus that are the basic components of all existing matter.

A - HIGH ENERGY RADIATIONS FOR MANKIND
(1958) 16 min. Color

This semitechnical film, for high school and college-level audiences, describes the principles, assembly and uses of the Van de Graaff particle accelerator to produce intense, stable, controlled beams of all basic radiation for basic and applied research, industrial processing, chemistry, metallurgy, and biology and medicine. It shows stages of assembly, testing and use of vertical and horizontal machines ranging from 1 to 6 million electron volts; the Microwave Linear Accelerator; and the 10-Mev Tandem Van de Graaff for exploring the binding energy of heavier elements. Examples include use for basic research, nuclear engineering, petrochemistry, drug sterilization, food preservation, radiography, and cancer treatment.

FOM-631 Filmstrip
Particle Accelerators

AUDIO-VISUAL AIDS

A - HIGH ENERGY PHYSICS RESEARCH
23 min. Color

Some 20 very high energy accelerators, scattered throughout the world, are being used to probe the characteristics of subatomic particles. The new particles and their interactions have brought about reconsideration and revision of some of the fundamental laws of physics. This technical film indicates our current understanding of subnuclear particles, nuclear forces, and surveys the status of high energy physics research in the United States. This includes the general types of accelerators and the devices used for particle detection and analysis, the efforts to organize the data into a unified general theory, the difficulty of this problem, and the many remaining questions.

THE LINEAR ACCELERATOR
12 min. B & W, McGraw-Hill 603505

This film introduces the theory of nuclear transmutations and the production of hard X-rays with laboratory accelerated particles. It shows the development of equipment and techniques from the original Cockcroft and Walton experiments up to the most recent travelling wave linear accelerator, the design and underlying theory of which are described in detail.

CONTENT	LEARNING EXPERIENCES
3. RADIOACTIVE DECAY A. Units of Radioactive Decay B. The Decay Equation 1. Derivation 2. Decay Constant 3. Half-Life a. Arbitrary decay units 1. The curie 2. Mass units 3. Dose units 4. Decay rate and decay scheme b. Using the Decay Equation c. Graphic Methods	1. If students have good math background, derive decay equation. 2. Show different variations of decay equation. 3. Assign half-life problems. 4. Lab Experiment: Determination of Half-Life. Chase et al pp. 48 Hermias & Joecile pp. 94

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 80-85 Harvey pp. 6-13 Choppin pp. 28-29 Dance pp. 7-11	

CONTENT	LEARNING EXPERIENCES
C. Decay Equilibria 1. Mixtures of Independently-decaying nuclides 2. Secular Equilibrium 3. Transient Equilibrium 4. Equilibrium Applications a. Sources of short half-life radioisotopes b. Radioisotope milkers	1. Demonstrate secular equilibrium with $^{137}Cs/^{137}Ba$ radioisotope milker. 2. Laboratory Experiment: Separation of Equilibrium Mixtures RaDEF $^{238}U/^{234}Th$ Chase et al pp. 115, 117, 119 Hermias & Joecile pp. 125, 130

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 85-88 Harvey pp. Choppin pp. 31-37 Dance pp.	RSS-5 Filmstrip Paper Radiochromatography

CONTENT	LEARNING EXPERIENCES
D. Modes of Decay 1. Heavy Nuclides a. Alpha emission 2. Nuclides of High N/P Ratio a. Beta Emission b. Gamma Emission 3. Nuclides of Low N/P Ratio a. Positron Emission b. Electron Capture 4. Excited Nuclides a. Isomeric Transitions b. Internal Conversion E. Decay Schemes 1. Simple 2. Complex	LABORATORY EXPERIMENT: <u>Mixture of Independently Decaying Activities</u> Chase et al, p. 52

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 19-36 Harvey pp. 43-56 Choppin pp. 37 Dance pp. 4-7	U-238 RADIOACTIVE SERIES 9 min. B & W, McGraw-Hill 626604 The film traces the various stages in the decay of U-238 to stable lead. Alpha emission, beta emission and the statistical nature of the process are emphasized. A brief mention is made of other radioactive series.
Overman pp. 19-22 Harvey pp. Choppin pp. Dance pp.	

CONTENT	LEARNING EXPERIENCES
4. PROPERTIES AND BEHAVIOR OF NUCLEAR RADIATIONS A. Types of Interactions of Radiation With Matter B. Alpha Particles 1. Structure 2. Source 3. Energy 4. Velocity 5. Range 6. Types of interactions a. Ionization b. Scattering	1. Assign properties of radiation to be collected in chart form by students. 2. Show differences between alpha and beta tracks by means of cloud chambers. Chase et al pp. 64 Hermias & Joecile pp. 35 3. LABORATORY EXPERIMENT: Range of Alpha Particles Chase et al pp. 89 Hermias & Joecile pp. 74

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 38-45 Harvey pp. 71-75 Choppin pp. 39-43 Dance pp.	A - PROPERTIES OF RADIATION (1962) 30 min. B & W (Overman Series) This film includes a discussion of general problems of radiation decay, such as the laws of radioactive decay, including the concept of half life. Statistical considerations are introduced, and the basic notion of the standard deviation in counts expected in various experiments is described. The energy spectrum from alpha and beta emitters is considered, and the use of absorption curves to study the energy distribution of beta radiation is introduced. The density thickness expressed in milligrams per square centimeter is introduced as a useful term. The film also considers problems of self-absorption, specific activity, and back-scattering of radiation. A - ALPHA, BETA, AND GAMMA (1962) 44 min. B & W (Overman Series) The film gives some insight into the origin and nature of alpha, beta, and gamma radiation. After a short discussion of the methods of describing atoms and the introduction of the energy-level concept, the lecturer introduces the potential-energy well model of the nucleus. This, together with the barrier model, is used as the frame of reference for a variety of other nuclear concepts. The energetics in alpha emission and the Gamow tunneling effect are used to describe alpha-ray emission and the energy levels in the nucleus. The lecturer discusses neutron absorption leading to the formation of nuclei having neutron-proton ratios differing from stable or naturally occurring nuclei. The transformation of excess neutrons into negative beta radiation and the return to stability are considered in some detail. Similarly, gamma radiation arising from a nuclear cooling process is described. The nuclear well model is then used to introduce decay schemes. INVISIBLE BULLETS (1962) 29 min. B & W This film introduces the series and establishes the basic knowledge about radiation necessary for an understanding of the other films in the series. The meaning of radiation, its natural sources, the various forms it takes, and how it is used in research are explained. The difference between alpha and beta particles and between gamma rays and X-rays is described.

CONTENT	LEARNING EXPERIENCES
C. Beta Particles 1. Structure 2. Source 3. Energy spectra 4. Velocity 5. Range 6. Types of Interactions a. Scattering b. Ionization c. Bremsstrahlung d. X-ray production e. Deflection by magnetic field 7. Absorption a. Absorption coefficients b. Range-energy relationships	1. Demonstrate deflection of beta particles by magnetic field. Chase et al pp. 99 Hermias & Joecile pp. 83 2. Demonstrate scattering of beta particles Chase et al pp. 23, 27, 30 Hermias & Joecile pp. 85 3. LABORATORY EXPERIMENT: <u>Absorption of Beta Radiation</u> Chase et al pp. 96 Hermias & Joecile pp. 78

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 38-45 Harvey pp. 71-75 Choppin pp. 44-46 Dance pp. 12	A - NUCLEAR RADIATIONS (1963) 30 min. B & W (Overman Series) This segment of the series continues the discussion of the film "Understanding the Atom: Alpha, Beta, and Gamma," and involves some of the basic concepts of nuclear reactions. Use is made of the nuclear well model as a useful teaching diagram. Neutron capture processes are described with the gamma emission and particle ejection reactions being studied. Nuclear fission is also discussed. As an example of the calculations involved in nuclear reactions, the film describes the activation of a gold sample in a nuclear reactor. Emphasis is placed on the minute quantities which can be detected with the subsequent applications to the technique of activation analysis. It is shown that hundredths of a part per billion of certain materials can be detected by nuclear techniques. RADIOACTIVITY 12½ min. Color, McGraw-Hill 612016 A description of the basic characteristics of alpha, beta, and gamma radiation and the instruments and methods by which they may be detected and measured in terms of charge and mass. Attention is then focused on the nucleus of the atom as the source of radiation.

CONTENT	LEARNING EXPERIENCES
D. Gamma Radiations 1. Structure 2. Source 3. Energy spectra 4. Range 5. Types of Interactions a. Photoelectric effect b. Compton scattering c. Pair production d. Rayleigh scattering e. Photo disintegration f. Nuclear resonance scattering g. Bragg scattering 6. Absorption a. Absorption coefficients b. Half-value layer c. Geometry	1. LABORATORY EXPERIMENT: <u>Inverse Square Law</u> Chase et al pp. 93 Hermias & Joecile pp. 70 <u>Absorption of Gamma Radiation</u> Chase et al pp. 104 Hermias & Joecile pp. 82

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 45-53 Harvey pp. 75-77 Choppin pp. 46-50 Dance pp. 13-15	

CONTENT	LEARNING EXPERIENCES
E. Neutrons 1. Structure 2. Sources a. Natural sources-radioisotopes b. Generators c. Fission 3. Energy classifications 4. Types of interactions a. Elastic scattering b. Resonance scattering c. Capture reactions 1. Activation 2. Transmutation 3. Spallation 5. Cross-section relations	1. If college or industrial laboratory is in the general area, a Field Trip to view a neutron howitzer could be made. If a neutron howitzer is available, many experiments could be performed.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. Harvey pp. 61 Choppin pp. Dance pp. 15	

CONTENT	LEARNING EXPERIENCES
5. NUCLEAR RADIATION DETECTION A. Ionization Review B. Detectors Dependent Upon Ion Collection 1. Ionization Chambers a. Electroscopes b. Electrometers c. Dosimeters 2. Geiger Counters 3. Proportional Counters 4. Modified Counters a. Windowless flow counters b. Neutron detectors C. Detectors Not Dependent Upon Ion Collection 1. Scintillation Counters a. Basic types b. Spectrometry c. Liquid scintillation counters 2. Photographic Emulsions a. Nuclear emulsions b. Autoradiography c. Film badges 3. Cloud Chambers D. Newer Counter Types 1. Solid-state detectors 2. Bubble chambers 3. Spark Chambers	1. Demonstrate simple flask-type electroscope 2. Pass around class old, broken end-window Geiger tube. 3. Pass around simple spinthariscope. Discuss how great strides were made with extremely crude equipment. 4. LABORATORY EXPERIMENTS: <u>Ionization Chambers</u> Chase et al pp. 57 Hermias & Joecile pp. <u>Scintillation Counters</u> Chase et al pp. 60 Hermias & Joecile pp. 58 <u>Proportional Counters</u> Chase et al pp. Hermias & Joecile pp. 56 <u>Autoradiography</u> Chase et al pp. 62 Hermias & Joecile pp. 64

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 58-79 Harvey pp. 77-84 Choppin pp. 50-61 Dance pp. 17-26 A - PRIMER ON MONITORING (1949) 27 min. Color The film discusses the basic makeup of atoms and types of radioactivity. Principles of radiation detection and measuring instruments are displayed, including a method of calibrating survey meters. The film also illustrates the penetrative ability of the various types of radiation encountered in monitoring and sets forth radiation-monitoring procedures best used in a chemical laboratory. (Some of the instruments used in this film are obsolete by current standards, although the principles involved and discussed are still valid.) A - RADIATION DETECTION BY IONIZATION (1962) 30 min. B & W (Overman Series) The basic principles of ionization detectors are described, particularly in relation to the pulse height as a function of voltage curves. Brief descriptions of ionization chambers, proportional counters, and Geiger counters are included, and examples of instruments operating in these regions are shown. Special consideration is given to Geiger counters, including the mechanism of gas quenching and the determination of a counting-rate plateau. The resolving time of a counter is discussed, as well as various components of a practical instrument, including amplifiers and scalers.	A - RADIATION DETECTION BY SCINTILLATION (1962) 30 min. B & W (Overman Series) A short review of gamma interactions with matter is shown, with particular reference to useful scintillation crystals. The scintillation process is described, and the efficiency of the conversion of gamma radiation to visible light in the scintillator is discussed. Solid and liquid scintillators are shown along with special detection devices using this principle. A description of the operation of a photomultiplier tube is given, and the concept of pulse height is developed. The principle of operation of a pulse-height analyzer is shown, and the spectrum obtained with such an instrument is shown and discussed. Brief mention is made of solid-state radiation detectors. A - LIQUID SCINTILLATION COUNTING (1958) 14 min. Color This film describes the use of a liquid scintillator for counting low-energy beta emitters commonly used in biological and medical tracer experiments. It also explains the advantages of the single- and double-photomultiplier tube liquid scintillation counters over the solid-phase and gas-phase counters, e.g., ease of sample preparation, high efficiency, and excellent sensitivity. The film describes counting techniques, how the counters work, and how a sample is prepared. Liquid scintillation counting is an extremely useful technique, particularly for weak beta emitters, such as ^{14}C and tritium, where the number of samples to be counted places a premium on the ease of sample preparation. FOM - 641 FILMSTRIP Radiation Detection

CONTENT	LEARNING EXPERIENCES
6. NUCLEAR RADIATION MEASUREMENT A. Basic Relationships 1. Absolute vs. Relative Measurements 2. Standards of Radioactivity 3. Decay Rate vs. Dose Rate	1. LABORATORY EXPERIMENT: <u>Geiger Counter Efficiency</u> Chase et al pp. 17 Hermias & Joecile pp. 51
B. The Detector and Its Environment 1. Background 2. Resolving Time 3. Instrument Efficiency C. Physical Relationship Between Sample and Detector 1. Physical Geometry - Inverse Square Law 2. Scattering a. Backscattering b. Sidescattering 3. Absorption of Radiation Before Detection a. Air absorption b. Window absorption	1. LAB EXPERIMENT OR DEMONSTRATION: a. <u>Inverse Square Law</u> b. <u>Sidescattering</u> Chase et al pp. Hermias & Joecile pp.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp.	RSS-1 Filmstrip
Harvey pp. 84-86	Sample Preparation
Choppin pp.	
Dance pp. 26-27; 31-32	
Overman pp. 68-69	
Harvey pp.	
Choppin pp.	
Dance pp. 27-30	

CONTENT	LEARNING EXPERIENCES
D. Influence of the Radioactive Sample Itself 1. Self-absorption 2. Sample shape 3. Random Decay & Counting Statistics	LABORATORY EXPERIMENT: Statistics of Counting Chase et al pp. 45 Hermias & Joecile pp. 62
E. Influence of Method of Sample Preparation 1. Duplicate samples 2. Carrier-free solutions 3. Use of carriers	LABORATORY EXPERIMENT: Carrier-free Solutions Chase et al pp. 41
7. IDENTIFICATION OF NUCLIDES A. Criteria for Identification 1. Chemical Properties 2. Half-Life 3. Types of Emitted Radiations 4. Energies of Emitted Radiations 5. Other Methods	LABORATORY EXPERIMENT: Beta Decay Energy Chase et al pp. 101

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 88-94	
Harvey pp.	
Choppin pp.	
Dance pp. 36-39	
Harvey pp. 83	
Choppin pp. 90-92	
Dance pp. 32-36	

CONTENT	LEARNING EXPERIENCES
8. HEALTH PHYSICS A. Sources of Radiation 1. Natural 2. Artificial B. Units of Dose 1. Method of Definition a. Number of disintegrating atoms b. Amount of energy absorbed 2. Dose Units a. The Roentgen b. The Rad c. The Rem d. The Rep C. Type of Radiation and Irradiation 1. Alpha 2. Beta 3. Gamma 4. Neutron	1. Demonstrate CD monitoring equipment: dosimeters, V-700 survey meters, gamma survey meters. 2. Make list of natural and artificial sources of radiation. 3. Show radioactive watch dials, radioactive Fiestaware dishes from '40's.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 53-57 Harvey pp. Choppin pp. Dance pp. 55-58; 64-69 Overman pp. 53-57 Harvey pp. Choppin pp. Dance pp. 59-64	RADIOLOGICAL SAFETY (1963) 30 min. B & W This film examines the field of radiological safety or health physics, and tries to give a basis for a perspective on potential biological radiation damage. It first considers background radiation and the nature of the difference in this radiation. Larger doses of radiation can be a potential cause of both somatic (direct bodily) damage and genetic (hereditary) damage, and consideration is given to the maximum permissible limits or radiation guide levels which have been extablished by various radiological protection committees and the Federal Radiation Council. Various units are described, with these including the roentgen, the rad, and the rem. The latter unit is a measure of the biological dose equivalent and considers the relative biological effectiveness (RBE) of the radiation. Consideration is also given to the maximum permissible concentration of radioisotopes in water or air, and the problems involved in the localization of radioactive materials in the body. Various factors that must be controlled in reducing the radiation hazard include the quantity of radioactive material, the distance, the time of exposure, and shielding. Internal exposure must be minimized by the use of special laboratory facilities and techniques which are required to minimize the admission of radioactive isotopes into the body. The importance of having calibrated instruments available is stressed in any program involving the use of radiation sources.
PHYSICAL PRINCIPLES OF RADIOLOGICAL SAFETY (PMF-5145-E). (1950) 51 min. Sale price: $66.36. For loan source see Army Field Library Listing, page 74. This film introduces concepts of internal and external and acute and chronic radiation exposure by means of a historical sequence on hazards associated with X-ray and radium therapy and radium-dial painting. A discussion of ionization from external and internal sources of alpha, beta, and gamma radiation, with detailed explanations of roentgen and "equivalent" or "energy" roentgen, is presented. Maximum permissible exposure and the theory of radiation-measuring instruments are also discussed. Formulas are developed for computing dosage rates from internal sources. Concepts of single and continued uptake, physical decay, and biological elimination of activity, biological half life, and effective half life are considered. The responsibility of the radioisotope user to other members of the laboratory and to the public is emphasized.	

CONTENT	LEARNING EXPERIENCES
D. Radiation Sickness 1. Mechanism In Mammals 2. Acute Radiation Syndrome a. Dose and symptoms b. LD-50 c. Individuality d. Long-range effects 3. The Chronic, Low-level Dose a. Dose and symptoms b. Long-range effects 4. Treatment of Radiation Sickness 5. Prevention of Radiation Sickness a. Distance b. Time c. Shielding E. Genetic Effects	1. Secure irradiated tomato seeds (Oak Ridge Atom Industries) and plant. Compare different dose rates and their effects. This company has many other irradiated materials for educational materials. 2. Show sample of pre-war orange Fiestaware dishes which were made with a uranium glaze. Calculate dose rate from using these dishes. 3. Compare different radioactivity watch dials for activity, with and without crystal if possible.

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 53-57 Harvey pp. Choppin pp. Dance pp.	RSS-7 Filmstrip Radiological Monitoring RSS-4 Filmstrip Radiation Safety

CONTENT	LEARNING EXPERIENCES
9. APPLICATIONS OF RADIONUCLIDES IN CHEMISTRY A. Tracer Applications 1. Isotope dilution 2. Radiometric analysis 3. Activation analysis B. Radiation Chemistry C. Separation Techniques 1. Chromatography 2. Electrophoresis 3. Precipitation 4. Solvent Extraction 5. Ion-exchange 6. Other methods	LABORATORY EXPERIMENTS: <u>Separation by Solvent Extraction</u> Chase et al pp. 119 Hermias & Joecile pp. 125 <u>Separation by Paper Chromatography</u> Chase et al pp. 120 Hermias & Joecile pp. 127 <u>Separation by Precipitation</u> Chase et al pp. 117 Hermias & Joecile pp. <u>Isotope Dilution Analysis</u> Chase et al pp. 123 Hermias & Joecile pp. 136 <u>Synthesis of a Labeled Compound</u> Chase et al pp. 126 Hermias & Joecile pp. <u>Determination of Solubility</u> Chase et al pp. 128 Hermias & Joecile pp. 122

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 99-110 Harvey pp. 103-114 Choppin pp. 113-135 Dance pp.	THE ATOMIC FINGERPRINT (1964) This film explains neutron activation analysis, a highly sensitive and powerful analytical technique with wide applications in the basic and applied sciences, which involves the use of neutrons to make substances radioactive, followed by analysis of the radiations emitted, to determine which elements are present and their amounts. The film demonstrates some of the many applications of neutron activation analysis in crime detection, geology and soil science, analysis of art and archeological objects, oil refining, agriculture, electronics, biology and medicine, and space sciences. RSS-5 FILMSTRIP Paper Radiochromatography
THE ART OF SEPARATION (1962) 29 min. B & W This film deals with the separation of chemical compounds into basic substances in the purest form possible by the process known as chromatography and with the importance of that process in chemistry work. Using radiation, the chemist is able to work with much greater speed and ease in the field of chromatography. The basic principles and various methods of modern chromatography are explained and demonstrated. Actual separation of a chemical compound is shown. RADIATION EFFECTS IN CHEMISTRY (A Geneva - 1964 film). 13 min. Color This technical film explains that radiation initiates a wide variety of chemical reactions. But the fundamental mechanisms which produce these effects are still under investigation. Within a few nanoseconds after irradiation, a variety of chemical substances are produced which are then available to participate in subsequent reactions. The experimental study of this process requires extremely sensitive and high-speed techniques - spectrometry, electron spin resonance techniques, etc.	TRANSURANIUM ELEMENTS 23 Min. Color, Chem. Study #4178 This film, produced in the Lawrence Radiation Laboratory of the University of California, Berkeley, features four scientists who were principals in the discovery and identification of several of the transuranium elements. Glenn Seaborg reviews the historical problem of the placement of the transuranium elements in the periodic table. Burris Cunningham performs experiments showing that neptunium, plutonium, and americium have chemical properties similar to those of uranium, but that under the same experimental conditions curium behaves like its rare-earth homolog, gadolinium. Stanley Thompson demonstrates how the ion-exchange separation technique is used in identification, using actual solutions of curium, berkelium, californium and einsteinium. Albert Ghiorso discusses the methods used in the synthesis of elements 102 and 103, and proposes a similar type of reaction which may lead to the discovery of element 104.

CONTENT	LEARNING EXPERIENCES
10. APPLICATIONS OF RADIONUCLIDES IN THE BIOLOGICAL SCIENCES	LABORATORY EXPERIMENTS:
A. Tracer Applications	<u>Absorption of Phosphate by a Plant</u> Chase et al pp. 71 Hermias & Joecile pp. 140
1. Tracing pathways of elements in plants and animals	<u>Distribution of Phosphate in a Plant</u> Chase et al pp. 74 Hermias & Joecile pp. 140
2. Finding tumors	<u>Absorption of Phosphate by Frogs</u> Chase et al pp. 79 Hermias & Joecile pp. 158
3. Investigating organs and metabolic rates	<u>Blood Volume</u> Chase et al pp. 83 Hermias & Joecile pp. 170
4. Effect of radiation on organisms	<u>Effects of Radiation on Germination of Seeds</u> Chase et al pp. Hermias & Joecile pp.
B. Radiation Biology	<u>Uptake of Iodine-131 by the Thyroid Gland</u> Chase et al pp. Hermias & Joecile pp. 166
1. Somatic Biology	<u>Absorption of Carbon Dioxide by Plants</u> Hermias & Joecile pp. 173
2. Genetic Effects	

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp.	RSS-2 FILMSTRIP
Harvey pp. 105, 106, 113	Autoradiography
Choppin pp.	
Dance pp.	RSS-3 FILMSTRIP
	Radiation Biology: Wet Ashing Techniques

CONTENT	LEARNING EXPERIENCES
11. APPLICATIONS OF RADIONUCLIDES IN INDUSTRY A. Power Applications 1. Energy from fission 2. Energy from fusion 3. Energy from radioactive decay B. Tracer Applications C. Radiation Applications 1. Utilizing effect of matter on radiation a. Thickness gauging b. Density gauging c. Depth gauging 2. Utilizing effect of radiation on matter a. Production of new biological species b. Irradiation sterilization c. Radiation-induced chemical reactions	1. Show model of nuclear reactor; demonstrate its mechanics. 2. Show AEC transparencies 3. LABORATORY EXPERIMENTS: a. <u>Depth Gauging</u> Chase et al, pp. 139 Hermias & Joecile pp. 105 b. <u>Detergent Efficiency</u> Chase et al pp. 146 Hermias & Joecile pp. 120 c. <u>Wear Testing</u> Chase et al pp. 144 Hermias & Joecile pp. 111 d. <u>Strain Gauging</u> Chase et al pp. 136

TEXT REFERENCES	AUDIO-VISUAL AIDS
Overman pp. 95-110 Harvey pp. 112-114 Choppin pp. 113-135 Dance pp.	ATOMIC FURNACES (1962) 29 min. B & W The operation, principles, and scientific applications of nuclear reactors, used as research tools in various projects, are briefly described. Types of research that reactors and associated equipment make possible are shown at length. The Gamma Ray Spectrometer, the Neutron Chopper, and a new reactor designed specifically for high- and low-radiation experiments in biology are also described.
A - FUSION RESEARCH (1964) 22 min. Color This technical film describes the nature of thermonuclear research as illustrated by many of the current investigations of plasma production and confinement. The major obstacles to success are plasma oscillations and instabilities which result in plasma loss from the magnetic containers. The film gives a qualitative description of some of the instabilities, of energy loss through charge exchange and radiation due to contaminants; and also describes plasma measurements, which are now very sophisticated. Several research devices in the United States on which progress has been encouraging are described in the film.	A - THE NEW POWER (1965) 45 min. Color This nontechnical film, for all audience levels, tells how the National Reactor Testing Station in Idaho is furthering the USAEC's quest for economic nuclear power. Most of the more than 40 experimental nuclear reactors built, being built, or planned there are described either historically or currently, including the Navy's prototypes for the submarine Nautilus and aircraft carrier Enterprise; the internationally known testing reactor complex (MTR, ETR, ATR); the Idaho CHemical Processing Plant, the Army's mobile low power nuclear plant (ML-1); and the importance of breeding nuclear fuel as authorized by the two Experimental Breeder Reactor complexes, EBR-1 and EBR-II.

CENCO Color or B & W

NUCLEAR RADIATION SERIES (HIGH SCHOOLS)
Six quarter-hour films on the basic principles of radioactivity, its uses and effects.

Title	Color	B/W
Detectors*	58513	58512
Uses in Medicine	58515	58514
Uses in Earth Studies	58517	58516
Uses in Outer Space*	58519	58518
Uses in Industry	58521	58520
Fallout*	58523	58522

A - RADIOISOTOPE APPLICATIONS IN INDUSTRY
(1964) 26 min. B & W

This film discusses some of the practical, simple, and easily understood methods of putting radioisotopes to work in industry. The program features Dr. Paul C. Aebersold, Director, Division of Isotope Development, USAEC, who is introduced by Dr. Ralph T. Overman, Chairman, Special Training Division of the USAEC's Oak Ridge Institute of Nuclear Studies and regular lecturer of the series. Using actual radioisotope sources, Dr. Aebersold gives various demonstrations of the degree of their penetrating radiations, the extent to which several types of materials can reduce them and the sensitive methods of detecting them.

A - RADIOISOTOPES: SAFE SERVANTS OF INDUSTRY
(1963) 28 min. Color

With emphasis on safety, this film surveys the widespread uses of radioisotopes in industry. Animated explanations of the principles involved in radioisotope gauging instruments, tracing, and radiography are given. Applications of these principles are shown in various processes in the food industry, automotive research, road construction, heavy industry, oil refining and shipping, and system trouble-shooting.

A - ATOMIC APOTHECARY
(1954) 38 min. B & W

Film discusses radioisotope research in biology and medicine, including research in radioactive dust, calcium absorption in animals, and effects of radioiodine in their diet; use of astatine, effect on blood flow, oxygen tension studies, radioactive iron in bone marrow, arteriosclerosis, and use of cysteine.

A - ROUNDUP
(1960) 18 min. Color

This film describes the use of radiation to eradicate the screwworm fly in the southeastern United States, an insect pest that had caused large losses to livestock owners.

A - MAN AND RADIATION
(1963) 28 min. Color

This popular-level film, suitable for audiences from junior high school through college, discusses many aspects of radiation and offers a survey of their widespread beneficial applications in medicine, industry, agriculture, power and research. A historical survey of the discovery of radiation is followed by an animated explanation of different types of radiation, including alpha, beta, and gamma. A brief explanation of radioisotopes and how they are produced is given, followed by scenes depicting some of their uses, including the use of Calcium-47 to diagnose bone cancer. The detection and study of radiation by sensitive instruments is explained.

THE RADIOISOTOPE. METHODOLOGY (PMF-5145-D). 33 min.

This film contains a historical sequence showing the early work of Hevesy in studying plant metabolism with naturally occurring radio-lead, after which it explains seven criteria for setting up a tracer experiment: (1) radiochemical purity, (2) single chemical state, (3) elimination of exchange error, (4) knowledge of the degree to which the labeled molecules remain intact, (5) avoidance of isotope effect, (6) avoidance of chemical effects, and (7) avoidance of radiation effects. The film also illustrates the relative importance of economy of time and materials and accuracy by depicting a typical biological tracer experiment from the formation of an idea to the final results.

A[illegible]ov, I.
INSIDE THE ATOM (G. 8-12)
Abelard-Schuman, 1961. $3.00

Adler, Irving
INSIDE THE NUCLEUS (General Ref.)
John Day, 1963. $4.95

Atkinson, William G.
INTRODUCTION TO ATOMIC ENERGY
Rider, 1959. $1.35 (Gen. Ref.)

Barr, Donald
ATOMIC ENERGY: THE HOW & WHY WONDER BOOK (G. 5-7)
Wonder Books, 1961. $1.00

Born, Max
THE RESTLESS UNIVERSE (G. 8-12)
Dover, 1957. $1.95

Booth, Verne H.
THE STRUCTURE OF ATOMS (Gen. Ref.)
MacMillan, 1964. $2.95

Bush, George L. & Anthony A. Silvidi
THE ATOM: A SIMPLIFIED DESCRIPTION
Barnes, 1961. $1.25 (General Ref.)

Chase G. & Rabinowitz, J.
PRINCIPLES OF RADIOISOTOPE METHOD-OLOGY
Burgess, 1962. $6.00 (Gen. Ref.)

Chase, G., Rituper, Jr., S. & Sulcoski, J.
EXPERIMENTS IN NUCLEAR SCIENCE(.7-12)
Burgess, 1964 $3.50

Choppin, Gregory R.
NUCLEI AND RADIOACTIVITY (Chem.Ref.)
W. B. Benjamin, 1964. $1.95

Cronkite, Eugene P. & Victor P. Bond
RADIATION INJURY IN MAN (Biology)
Thomas, 1960. $6.50

Dance, J. B.
RADIOISOTOPE EXPERIMENTS FOR SCHOOLS & COLLEGES
Pergamon Press, 1967

Efron, Alexander
NUCLEAR ENERGY (Physics)
Rider, 1958. $1.80

Essp Research & Engineering Company
101 ATOMIC TERMS & WHAT THEY MEAN
Esso, 1960. Free (G. 8012)

Fermi, Laura
THE STORY OF ATOMIC ENERGY (G.8-12)
Random, 1961. $1.58

Ford, Kenneth W.
THE WORLD OF ELEMENTARY PARTICLES
Blaisdell, 1963. $2.95 (physics)

Frisch, Otto R.
ATOMIC PHYSICS TODAY (Physics)
Basic, 1961. $4.50

Gamow, George
THE ATOM AND ITS NUCLEUS (Gen. Ref.)
Prentice, 1961. $1.95

Glassner, A.
INTRODUCTION TO NUCLEAR SCIENCE
D. VanNostrand, 1961. $3.75 (G.7-12)

Glasstone, Samuel
SOURCEBOOK ON ATOMIC ENERGY (Gen.Ref.)
Nostrand, 1958. $4.40

Haber, Heinz
THE WALT DISNEY STORY OF OUR FRIEND THE ATOM (G. 8-12)
Golden Press. 1957. $5.00

Harvey, Bernard
NUCLEAR CHEMISTRY
Prentice-Hall, 1965. $1.95

Hermias & Joecile, Sisters
RADIOACTIVITY: FUNDAMENTALS AND EXPERIMENTS
Holt, 1963. $1.95

Helvey, T. C.
EFFECTS OF NUCLEAR RADIATION ON MEN AND MATERIALS
(Industry & Sci.)
Rider, 1959. $1.80

Hill, R. D.
TRACKING DOWN PARTICLES (physics)
Benjamin, 1963. $2.95

Lagowski, J. J.
THE STRUCTURE OF ATOMS (Ref.)
Houghton Miffin, 1964. $1.95

Lewellen, John B.
YOU & ATOMIC ENERGY & ITS WONDERFUL USES (G. 5-9)
Childrens Press, 1959. $2.00

Lot, F.
RADIOISOTOPES IN THE SERVICE OF MAN (Industry)
Unesco, 1958. $1.00

Overman, Ralph T.
BASIC CONCEPTS OF NUCLEAR CHEMISTRY
Reinhold, 1963. $1.95 (Chem.)

Putman, J. L.
ISOTOPES (General Reference)
Atomic Energy Research, 1960 $1. 95

Seaborg, Glenn T.
MAN-MADE TRANSURANIUM ELEMENTS
Prentice, 1963. $3.95

UNDERSTANDING THE ATOM SERIES

Published as part of the AEC's educational assistance program, the series includes these titles:

Accelerators
Animals in Atomic Research
Atomic Fuel
Atomic Power Safety
Atoms at the Science Fair
Atoms in Agriculture
Atoms, Nature, and Man
Careers in Atomic Energy
Computers
Controlled Nuclear Fusion
Cryogenics, The Uncommon Cold
Direct Conversion of Energy
Fallout From Nuclear Tests
Food Preservation by Irradiation
Genetic Effects of Radiation
Microstructure of Matter
Neutron Activation Analysis
Nondestructive Testing
Nuclear Clocks
Nuclear Energy for Desalting
Nuclear Power and Merchant Shipping
Nuclear Power Plants
Nuclear Propulsion for Space
Nuclear Reactors
Nuclear Terms, A Brief Glossary
Our Atomic World
Plowshare
Plutonium
Power from Radioisotopes
Power Reactors in Small Packages
Radioactive Wastes
Radioisotopes and Life Processes
Radioisotopes in Industry
Radioisotopes in Medicine
Rare Earths
Research Reactors
SNAP, Nuclear Space Reactors
Sources of Nuclear Fuel
Synthetic Transuranium Elements
The Atom and the Ocean
The Chemistry of the Noble Gases
Whole Body Counters
Your Body and Radiation

A single copy of any one booklet, or of no more than three different booklets, may be obtained free by writing to:

USAEC, P. O. BOX 62, OAK RIDGE, TENNESSEE 37830

Complete sets of the series are available to school and public librarians, and to teachers who can make them available for reference or for use by groups. Requests should be made on school or library letterheads and indicate the proposed use.

Students and teachers who need other material on specific aspects of nuclear science, or references to other reading material, may also write to the Oak Ridge address. Requests should state the topic of interest exactly, and the use intended.

In all requests, include "Zip Code" in return address.

Abbreviation Listing by Title

ACCELERATORS	ACC
ANIMALS IN ATOMIC RESEARCH	AAR
ATOMIC FUEL	ATF
ATOMIC POWER SAFETY	APS
ATOMS AT THE SCIENCE FAIR	ASF
ATOMS IN AGRICULTURE	AIA
ATOMS, NATURE, AND MAN	ANM
CAREERS IN ATOMIC ENERGY	CAE
COMPUTERS	COM
CONTROLLED NUCLEAR FUSION	CNF
DIRECT CONVERSION OF ENERGY	DCE
FALLOUT FROM NUCLEAR TESTS	FNT
FOOD PRESERVATION BY IRRADIATION	FPI
GENETIC EFFECTS OF RADIATION	GER
MICROSTRUCTURE OF MATTER	MSM
NEUTRON ACTIVATION ANALYSIS	NAA
NONDESTRUCTIVE TESTING	NDT
NUCLEAR CLOCKS	NCL
NUCLEAR ENERGY FOR DESALTING	NED
NUCLEAR POWER AND MERCHANT SHIPPING	NPS
NUCLEAR POWER PLANTS	NPP
NUCLEAR PROPULSION FOR SPACE	NPR
NUCLEAR REACTORS	NRC
NUCLEAR TERMS, A BRIEF GLOSSARY	NTG
OUR ATOMIC WORLD	OAW
PLOWSHARE	PSH
PLUTONIUM	PLU
POWER FROM RADIOISOTOPES	PFR
POWER REACTORS IN SMALL PACKAGES	PRP
RADIOACTIVE WASTES	RAW
RADIOISOTOPES AND LIFE PROCESSES	RLP
RADIOISOTOPES IN INDUSTRY	RII
RADIOISOTOPES IN MEDICINE	RIM
RARE EARTHS, THE FRATERNAL FIFTEEN	REA
READING RESOURCES IN ATOMIC ENERGY	RAE
RESEARCH REACTORS	RER
SNAP: NUCLEAR SPACE REACTORS	SNP
SYNTHETIC TRANSURANIUM ELEMENTS	STE
THE ATOM AND THE OCEAN	AAO
WHOLE BODY COUNTERS	WBC
YOUR BODY AND RADIATION	YBR

FILMSTRIPS PREPARED BY THE

RADIATION SCIENCE SEMINAR STAFF

RSS #1 SAMPLE PREPARATION

This filmstrip details the preparation of liquid and solid samples, including use of planchets, card mounts, micro and macro equipment.

RSS #2 AUTORADIOGRAPHY

Using license-exempt radiophosphate, this strip shows how it may be used to trace the path of phosphorus in a tomato plant. Simple autoradiography apparatus is used, and alternate equipment is shown. Exposure calculations are shown for No-Screen X-Ray film. Suitable for all levels of biology classes and project work.

RSS #3 RADIATION BIOLOGY: WET ASHING TECHNIQUES

This filmstrip shows how radiophosphate is used in tracing the pathways of phosphorus in a frog, utilizing wet ashing techniques with nitric acid and later determination by Geiger counting. Data is not shown so the student may duplicate the experiment.

RSS #4 RADIATION SAFETY IN THE LABORATORY

This filmstrip details do's and don'ts of radiation safety in the small educational laboratory using Civil Defense monitoring equipment.

RSS # 5 PAPER RADIO CHROMATOGRAPHY

Utilizing ascending paper chromatography, the secular equilibrium mixture of U-238 and Th-234 is separated. The separated components are detected by both spraying and a radiochromotogram scanner. R_f value calculations are shown.

RSS #6 SECURING INEXPENSIVE NUCLEAR ACCESSORIES

This master of this strip was made completely by the RSS staff utilizing an inexpensive photographic process. Aimed primarily for teachers, it shows how inexpensive accessories such as resolving time sources, absorbers, tube stands, etc., may be made from inexpensive lucite plastic.

RSS #7 RADIOLOGICAL MONITORING IN THE LABORATORY

With Civil Defense equipment, basic monitoring techniques are shown for the small educational laboratory. Should be shown along with RSS #4, RADIATION SAFETY.

Until commercial distribution is arranged, write to the address below to secure copies of the filmstrips:

John W. Sulcoski, Director
Radiation Science Seminar
80 N. Washington St.
Wilkes-Barre, Pa. 18701

ATOMIC ENERGY COMMISSION MOVIES

* Insert
See Bottom of next column

SERIES: The "Challenge"
13 in-depth description of basic research films, all 29 min.

Request titles at least three weeks in advance - shipment from library is at government expense - return shipment costs are borne by the borrower, generally by parcel post and each reel insured for $100.

A IS FOR ATOM (Atomic energy principles)
15 min. color (1953)
ATOMIC POWER AT SHIPPING PORT (power reactor)
30 min. color (1958)
ATOMIC WEATHERMAN (application) 18 min. color (1963)
BETA RAY SPECTROMETER (physics) 7 min. color (1963)
CONTROLLING ATOMIC ENERGY (fundamentals)
13 min. color (1961)
POWER REACTORS (power reactor) 55 min. color (1958)
INTRODUCING ATOMS AND NUCLEAR ENERGY 11 min. (1963)
UNLOCKING THE ATOM (fundamentals) 20 min. (1950)
NAVAL RESEARCH LABORATORY REACTOR (research)
21 min. color (1958)
PRODUCTION OF URANIUM FEED MATERIAL (handling)
28 min. color (1959)
THE PETRIFIED RIVER (prospecting) 28 min. color (1956)
THE NEW POWER (power reactor) 39 min. color (1963)
UNDERWAY (nuclear propulsion) 20 min. color(1960)
ATOMS FOR SPACE (space) 28 min. color (1962)
THE HIGH ENERGY PEOPLE (research)5 min.color(1963)
ISOTOPES (Production & handling) 20 min. color (1965)
RADIOISOTOPES: SAFE SERVANTS OF INDUSTRY (industrial)
28 min. color (1963)
RADIATION IN BIOLOGY: AN INTRODUCTION (biology)
13 min. color (1962
HARVEST OF AN ATOMIC AGE (agriculture)
20 min. color (1963)
MEDICINE (medicine) 20 min. color) 1957
RADIATION IN PERSPECTIVE (radiation hazard)
43 min. color (1963)
MAN AND RADIATION (application) 41 min. color (1963)
ATOMIC ENERGY - A FORCE FOR GOOD (peaceful uses)
25 min. b & w (1955)
THE INTERNATIONAL ATOM (peaceful uses)
27 min. color (1961)

PROJECT GNOME (nuclear explosives) 29 min. color(1963)
INDUSTRIAL APPLICATIONS OF NUCLEAR EXPLOSIVES
(industry) 11 min. color (1958)
GROUP SHELTER (nuclear weapons) 10 min. color (1960)
OPERATION CROSSROADS (nuclear weapons)
27 min. color (1948)

Audio-Visual Branch
Division of Public Information
U. S. Atomic Energy Commission
Washington, D. C. 20545

SERIES: "The Radioisotope" (black & white from 68 min. to 33 min.):

Fundamentals of Radioactivity
Practical Procedures of Measurement
The Radioisotope in General Science
Radioisotopes in Agriculture
The Radioisotope Methodology
Properties of Radiation
Practice of Radiological Safety
Principle of Radiological Safety

SERIES: "Understanding the Atom" (all about 30 min.):

Alpha, Beta & Gamma
Radiation & Matter
Properties of Radiation
Detection by Ionization
Detection by Scintillation
Nuclear Reactions

* F. T. Richardson, Director Public Information Service
U. S. Atomic Energy Commission, New York Operations office

GEIGER COUNTER

The Geiger counter is probably the most common unit used to detect radiation. It actually consists of two separate parts: the Geiger tube and a ratemeter. The Geiger tube is a gas-filled tube which contains a thin wire in the center which serves as a positive terminal, and a thin layer of a metal deposited on the inside of the glass tube. When a ray given off by a radioactive source enters the tube, it causes ionization of the gas inside. The ions formed drift to each electrode completing an electric circuit resulting in a pulse of electricity being sent to the ratemeter. The ratemeter accepts these pulses and converts them to a reading of the number of rays which enter the tube in a period of time,

The Conversion kit has been designed especially for use with ratemeters similar to the model CD V-700 with a side-window Geiger tube. The experiments may be performed with any other ratemeter, such as the Classmaster, which has side-window Geiger tube. The operating instructions may be slightly different.

The Geiger tube supplied with these instruments has a window thickness which prevents the passage of alpha and weak beta particles from entering the inside of the tube to be counted. Beta and gamma sources are detected easily.

The sources recommended for these experiments are Thallium-204, Radium-226, or Strontium-90 (pure beta-emitters), and Cobalt-60 or Barium-133,a gamma-emitter.

COUNTING GEOMETRY

For any radioactive measurement to be reproduced at a later time, the position of the source in relation to the Geiger tube must remain constant, or erratic results will be secured. This is the purpose of the tube stand, the heart of the conversion kit. It enables the experimenter to reproduce the original counting conditions at any future time.

Operating the Geiger counter with the kit is simple. Clamp the tube to tube stand so the window faces toward the hole in the tube stand. Turn the operating switch to x 100 and wait a few minutes for warm-up. The counter is now ready for making radioactive measurements.

SUPPLIERS OF RADIOACTIVE SOURCES FOR THESE EXPERIMENTS

Recommended sealed sources

#161	Sr-90	½ uc	Beta
#169	Tl-204	½ uc	Beta
#125	Cs-137	½ uc	Beta-gamma
#129	Co-60	½ uc	Beta-gamma

Recommended liquid sources

#223	1-131	10 uc
#227	?-32	10 uc

General Radioisotope Processing Corp.
3000 San Ramon Valley Blvd.
San Ramon, Calif. 94583

(This supplier is recommended only because of the fact that it has the lowest prices anywhere for most radioactive sources.)

EXPERIMENT 1 BACKGROUND

THE PROBLEM

Even though no sources may be present near the Geiger counter,natural radioactive substances in the air and ground, along with cosmic rays, will be detected by the instrument.

APPARATUS

Tube stand, Geiger counter; ear-phone, timer.

PROCEDURE

No sources should be near the instrument for this experiment.

1. Turn on the instrument and wait one minute for warm-up.

2. Plug the earphone, into the jack which is found at the lower left-hand side of the Geiger counter case.

3. With the aid of a watch, clock, or timer, listen with the earphone and count the number of clicks obtained in a minute time interval.

   List carefully to the clicks. Do they occur in an even spacing, or do they occur in a random fashion?

CONCLUSION

The background count must be subtracted from any readings obtained on the meter to secure the corrected activity of the sample.

EXPERIMENT 2 DISTANCE AND RADIATION

THE PROBLEM

Radiation is similar to light rays in many respects, as a light source is moved away from an object, the light shining on the object decreases in intensity. By placing a sample on the different shelves of the tube stand and determining the activity, you will determine the effect of increasing distance upon rays given off by radioactive substances.

APPARATUS

Geiger counter, tube stand, sample tray, beta and gamma sources.

PROCEDURE

1. Place a beta source in the sample tray and slide the sample tray into the first shelf of the tube stand. Record the activity of the sample when it is on the first shelf.

2. Place the sample tray on the second shelf of the tube stand and record the activity.

3. Repeat step No. 2 with the other shelves. Record all activities with the corresponding shelf numbers.

CONCLUSIONS

Convert all activities for background. Plot a graph of the data with shelf number on the abscissa against the corrected activity on the ordinate. What relation exists between distance and the intensity of radiation?

Whv are tube stands made with a number of shelves?

EXPERIMENT 3 ABSORPTION OF BETA RADIATION

THE PROBLEM

The penetration of radiation through matter is a very important factor in the study of radiation. A radioisotope from its penetration in different kinds of matter may be identified. Knowledge of the penetration of radiation is also important in selecting shielding for protection against radiation.

As radiation passes through matter, it is absorbed. You will study the absorption of beta rays by placing a number of absorbers between the source and the Geiger tube.

APPARATUS

Geiger counter, tube stand, sample tray, absorbers, beta source.

PROCEDURE

1. Place a beta source in the sample tray, and slide the sample tray into the second or third shelf of the tube stand. Record the activity of the sample with no absorber in a data chart.

2. Place an absorber slide in the shelf directly above the radioactive source. Record the activity of the sample with one absorber.

3. Determine the activity of the sample with two absorbers and record. Repeat by increasing the number of absorbers in the same shelf.

CONCLUSIONS

Correct all activities for background. Plot a graph of the data with number of absorbers on the abscissa against the corrected activity on the ordinate. From the graph, what relation exists between absorber thickness and intensity of radiation?

EXPERIMENT 4 ABSORPTION OF GAMMA RADIATION

THE PROBLEM

In experiment No. 3, you investigated the absorption of beta particles by matter. You will perform a similar experiment to determine if gamma rays are absorbed in the same manner.

APPARATUS

Geiger counter, tube stand, sample tray, absorbers, gamma source.

PROCEDURE

1. Place a gamma source in the sample-tray and slide the sample tray into the second or third shelf of the tube stand. Record the activity of the sample with no absorber in the data chart.

2. Place an absorber slide in the shelf directly above the radioactive source. Record the activity of the sample with one absorber.

3. Determine the activity of the sample with two absorbers in place and record. Repeat by increasing the number of absorbers in the same shelf.

CONCLUSIONS

Correct all activities for background. Plot a graph of the data with number of absorbers on the abscissa against the corrected activity on the ordinate. From the graph, what relation exists between absorber thickness and the intensity of gamma radiation?

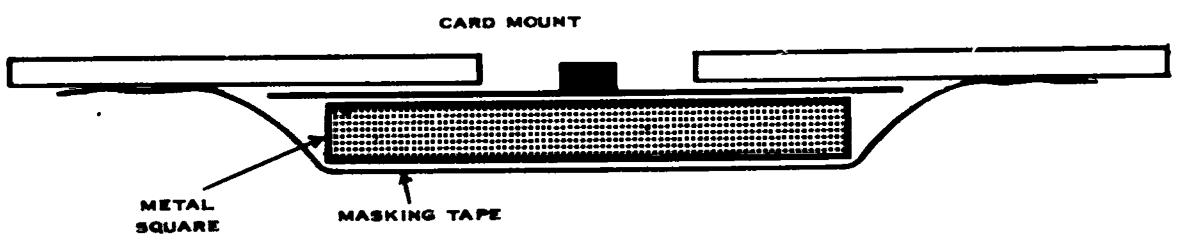
EXPERIMENT 5 SCATTERING OF RADIATION

THE PROBLEM

Since beta radiation is really composed of particles, the beta particle should be expected to bounce off matter in the same way a ball is bounced off a wall. This bouncing effect is called scattering when applied to radiation.

APPARATUS

Geiger counter, tube stand, absorbers, card mount, medicine dropper, 0.1 uc of I-131 or P-32, card mount, saran wrap, tape.



PROCEDURE

1. Tape a piece of saran wrap tightly over the hole in a card mount. Turn the prepared card mount over so the taped side faces the workbench.

2. Add 0.1 uc of I-131 or P-32 to the center of the saran wrap. The liquid should remain in the center. Do not use too much to cause the liquid to run all over the film.

3. Let the liquid dry naturally.

4. When the liquid has dried, slide the card mount into the second or third shelf of the tube stand. Record the activity.

5. Place an absorber slide in the shelf directly below the card mount. Record the activity of the sample with one absorber.

6. Determine the activity of the sample with two absorbers and record. Repeat by increasing the number of absorbers in the same shelf.

7. Determine the background count as in Experiment 1.

CONCLUSIONS

Correct all activities for background. Plot a graph of the data with number of backing absorbers on the abscissa against the corrected activity on the ordinate. Does the scattering increase as the backing thickness increases?

Try the experiment with absorbers of different material (but close to the same thickness), such as plastic, copper and lead.

EXPERIMENT 5 HALF-LIFE

THE PROBLEM

The half-life of a radioisotope is that time which it takes for the activity to reach one-half its original value. The simplest way to find the half-life is to determine the activity at different periods of time while the sample is decaying. The half-life may then be obtained from a graph of activity plotted against time.

APPARATUS

Geiger counter, tube stand, sample tray, sample pans, medicine dropper, 0.1 uc of I-131 or P-32.

PROCEDURE

1. With a medicine dropper, transfer the I-131 or P-32 to a sample pan. Allow the liquid to dry naturally in the air or heat it gently with a strong light bulb such as a spot lamp 0.1 uc of either radioisotope should supply enough activity. Either radioisotope may be obtained from commercial suppliers or from a hospital which uses the substances for treatment of patients. No AEC license is needed to use these small quantities. Up to ten uc may be used without a license.

2. When the liquid has dried, place the sample pan on the sample tray. Slide the sample tray into one of the shelves of the tube stand so the meter reading does not go off the largest scale on the counter. Determine the activity. Record the activity and the exact time and date.

3. Repeat step #2 every two or three days for two weeks. Record the exact time and date accurately.

4. When the experiment is completed, the sample may be disposed of by washing it off the sample pan in a stream of water. Use a large volume of water to wash it down the drain. Wash the hands carefully after handling the substance.

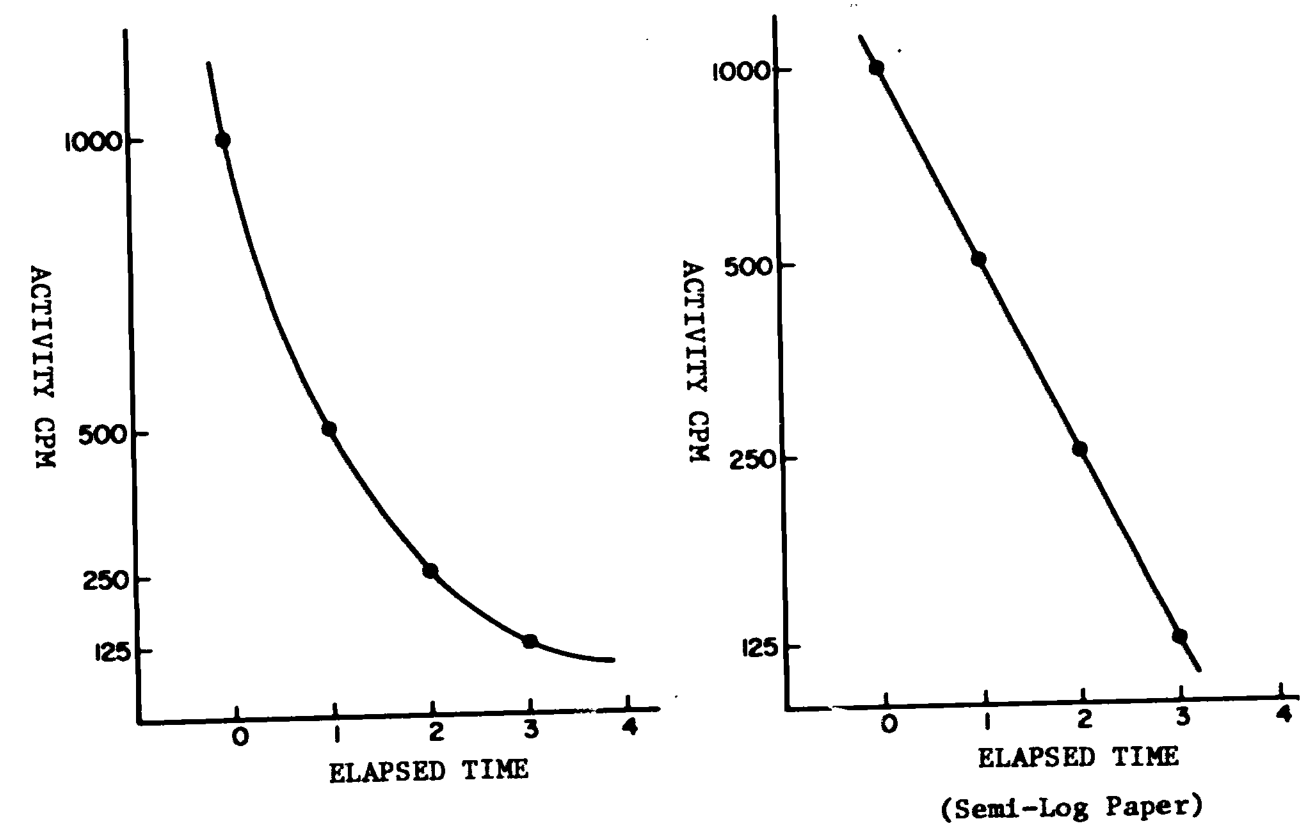


Figure 8. Half-life Curves

CONCLUSION

Correct all activities for background. On semi-log graph paper plot a graph of the data with the elapsed time in days on the abscissa against the corrected activity on the ordinate. On the ordinate, find the activity which is half the original activity. Find the spot on the abscissa which meets one-half the original activity. This value is the half-life.

Compare your result with the value given in the handbook. How accurate is your result?

AUTORADIOGRAPHY PROCESSING FORMULAS

The principles of the autoradiography process are much the same as those principles of the ordinary photographic process. The developable image is produced by ionizing radiation in autoradiography, while in ordinary picture-taking the developable image is usually produced by light rays from the ultraviolet to the infrared range. However, once the developable image is formed, the processing is the same.

The image must be developed, fixed and washed. In autoradiography, more contrasty developers are used to get a black and white image, where the ordinary photographer wants a complete scale from white to gray to black. These contrasty developers are usually more alkaline, and are essentially the same type used in the graphic arts.

Processing chemicals for autoradiography need not be purchased from suppliers; most chemical laboratories have all the chemicals needed but one or two, which may be purchased at the local photo shop. The teacher may then realize a tremendous savings, but may also have a wide variety of developer types to choose from by varying the formula.

The chemicals should be mixed in the order given. Tap water may be used. They may be stored in a brown, capped bottle filled right to the brim, unless they will be used immediately. The high-contrast developers have a short tray life; they can only be used once. D-82 has a tray life of only 2 hours. Persons susceptible to skin ailments should wear rubber gloves. Wash hands after using them, and label all bottles correctly and with a "POISON" label.

Kodak Elon and possible hydroquinone may not be found in the laboratory; these can be purchased at any quality photo shop. One pound of either of these chemicals lasts a long time. Other chemicals needed may be USP, NF, or purified grade; reagent grade chemicals are not needed. Do not use technical grade chemicals, however. Distilled water is not needed, as long as the water used in preparing the solutions is

Relatively soft.

High Contrast Developers for Autoradiography

Kodak Developer D-11
An excellent all-round high contrast developer. Affords the highest contrast without resorting to use of NaOH as the accelerator.

Water, about 125 F (50C)	500 cc
Kodak Elon Developing Agent	1.0 grams
Kodak Sodium Sulfite, desiccated	75.0 grams
Kodak Hydroquinone	9.0 grams
Kodak Sodium carbonate, monohydrated	30.0 grams
Kodak Potassium Bromide	5.0 grams
Cold water to make	1.0 liter

Develop about 4 minutes in a tray at 20 C.

Kodak Developer D-19

High contrast, but not as great as D-11. Longer development time. Possible best choice for autoradiography.

Water, about 125 F (50C)	500 cc
Kodak Elon Developing Agent	2.0 grams
Kodak Sodium Sulfite, desiccated	90.0 grams
Kodak Hydroquinone	8.0 grams
Kodak Sodium Carbonate, monohydrated	52.5 grams
Kodak Potassium Bromide	5.0 grams
Cold water to make	1.0 liter

Develop 5 minutes in a tray at 20C.

Kodak Developer D-82

Water, about 40C	700 ml
Methanol	100 ml
Kodak Elon Developing Agent	14 gm
Sodium sulfite, anhydrous	52.6 gm
Hydroquinone	14 gm
Sodium hydroxide	9 gm
Potassium Bromide	9 gm
Cold water to make	1 liter

Develop about 5 min. in a tray at 20C. Do not use at temperatures above 25 C; make certain room is well-ventilated because of the methanol. Do not get this developer on the hands; wash hands immediately after use.

This developer is useful when the autoradiogram is greatly underexposed; it has the most powerful developing action of any Kodak formula released to the public. Safelights must be kept away from the trays twice the usual distance when this developer is used, and even then some fogging is unavoidable. D-82 is a last-resort developer.

Stop Baths

Kodak Stop Bath SB-1a

Water	1.0 liter
*Kodak Acetic Acid, 28%	125 cc

* To make 28% Acetic Acid, dilute 3 volumes of glacial acetic acid (99%) with 8 volumes of water.

Fixing Baths

The fixing bath is important so the image can be made permanent. The following fixer has a high capacity and is very rapid in its fixing action. Films should be fixed for twice the time it takes the film to clear; prolonged fixing should be avoided, or bleaching action will commence.

Kodak Rapid Fixing Bath F-7

Water, about 50 C	600 ml
Sodium Thiosulfate	360.0 grams
Ammonium chloride	50.0 grams
Sodium sulfite, anhydrous	15.0 grams
Acetic Acid, 28%	48 ml
Boric Acid, crystals only	7.5 grams
Aluminum potassium sulfate (potassium alum)	15.0 grams
Cold Water to make	1.0 liter

Washing and Drying

To expedite washing and drying, the negatives may be placed in a solution containing 5 gm of sodium carbonate per liter for two minutes immediately after fixing to neutralize the fixer. This treatment will reduce washing time down to 5 minutes. For extreme permanence, wash the films for 20 minutes.

After washing, the films may be placed in a solution of Kodak Photo-flo solution to suppress water marks and for more even and rapid drying. A satisfactory substitute may be made by adding a few drops of any mild liquid detergent per liter of water. Do not use any detergent which may contain pine oil, bases, or other additions.

NUCLEAR EDUCATIONAL EQUIPMENT

The nuclear suppliers given on the next few pages are just a few of the many in the field, but these suppliers deal with educators or either have an educational division. All sell quality equipment.

In purchasing equipment, care must be taken so as not to over-purchase. If a scaler is to be used exclusively for G-M counting with license-free quantities, it is sheer folly to purchase an expensive, multi-use scaler and accessories for $800 when the same money could be used to purchase two $400 educational scalers and accessories. It is also more prudent to purchase one ratemeter and one scaler rather than one ratemeter/scaler combination for the same cost. By putting up the equipment for bids, more savings can be made.

Most of the experiments suggested in this curriculum guide may be performed with G-M counting systems and license-free quantities. Scintillation systems, proportional counters, gas flow counters, and other more sophisticated systems should be secured only after enough G-M systems have been secured for basic counting techniques.

Many low-priced scalers are available for educational use.

ITEM	Baird-Atomic	Cenco	Nuclear-Chicago	The Nucleus	Picker Nuclear	Welch Scientific
Scaler for G-M counting with H-V control	SC-355 Scalette 2 glow tubes + mech.register	71208-16 Binary type 71296 All decade	8151 2 decades + mech. register + preset count	Model K All glow tube(5)	600-010 All glow tube(5) timer included	2190B 3 glow tubes + mech. register
Ratemeter	RM-36B	71201-	6327	Model L	600-012	2192
Geiger tube, thin end-window 1.4-2.0 mg/cm^2 and tube stand	EWH-289 TS-275	71218 71204 71207	404	SG-1	610-431 600-137	2162A
Calibrated absorber set	AB-276	-	422	A-10	25-0221	2162C
Timer for scaler	PT-10-5	73425	8420	ET-100	-	2162D + 0842M 2190E
Radio assay Electroscope	RE-1050	71258	-	R-2	-	2189
Cloud Chamber, diffusion type	CC-278	71850	6311 6312	C-200	-	2158B 2195
Propipetter for 1ml pipettes	PRO-42	-	-	H-2	25-0424	
Micropipette Control	MPC-491	-	567580	H-1	25-0423	2190H
Micropipettes	TP-74	16369	567590	H-2	25-0422	2190H
Planchets	SAP-137	71224-3	3302	F-3	25-0345	2190H

All items above are not necessarily equal in features or price, although all will perform essentially as well for G-M counting. Other accessories, such as resolving time sources, absorber sets, conversion kits for Civil Defense instruments may be constructed as outlined in the RSS Filmstrip, "Securing Inexpensive Nuclear Accessories." As manufacturers constantly change their lines, no claim for completeness or accuracy can be made for such a list.

NAMES AND ADDRESSES OF NUCLEAR EQUIPMENT SUPPLIERS TO HIGH SCHOOLS

COUNTING EQUIPMENT AND ACCESSORIES

Baird-Atomic, Inc.
Atomic Accessories Division
33 University Road
Cambridge, Mass. 02138

Central Scientific Company
1700 West Irving Park Road
Chicago, Ill. 60613

Nuclear-Chicago Corp.
333 East Howard Avenue
Des Plaines, Ill. 60016

The Nucleus
P. O. Box R
Oak Ridge, Tenn. 37830

Picker Nuclear
25 South Broadway
White Plains, New York 10600

Welch Scientific Company
7300 North Linder Avenue
Skokie, Illinois 60076

ACCESSORIES AND SPECIALIZED EQUIPMENT

Nuclear Associates, Inc.
35 Urban Ave.
Westbury, L.I. New York 11590

Oak Ridge Atom Industries
Educational Products Division
500 Elza Drive, P. O. Box 429
Oak Ridge, Tenn. 37831
(Irradiated Seeds)

Atomic Corporation of America
7901 San Fernando Road
Sun Valley, Calif. 91352
(Low-cost autoradiography kit)

General Radioisotope Processing Corp.
3000 San Ramon Valley Blvd.
San Ramon, Calif. 94583
(Low-cost radio-active sources)

Bio-Rad Laboratories
32nd and Griffin Avenue
Richmond, California 94800
(Heavy Water, low cost)